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VOLUME III

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MAMMALIA

FAUNAS FROM THE PACIFIC AND GREAT BASIN REGIONS

TERTIARY VERTEBRATE FAUNAS OF THE NORTH COALINGA REGION OF CALIFORNIA

A CONTRIBUTION TO THE STUDY OF PALÆONTOLOGIC CORRELATION IN THE GREAT BASIN AND PACIFIC COAST PROVINCES

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Paper presented before the American Philosophical Society, April 24, 1915. *Transactions of the American Philosophical Society*, n. s., vol. 22, pt. 3, pp. 191–234, November 1915.

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INTRODUCTION

One of the most important problems in West-American palæontology and geology concerns the definite determination of time relations between the Pacific Coast marginal marine deposits and the sequence of continental formations of the Great Basin province. While similar time scales have been used in the regions east and west of the Sierra-Cascade Range, lines distinctly connecting the geological columns of these two regions are rare. Until recently, remains of the flora have been almost the only means of correlation, but we have known very few satisfactory occurrences of plants appearing in both areas. Marine invertebrates, found in a remarkably full faunal sequence in the Tertiary marginal marine province, and furnishing the principal materials for correlation between the areas or subdivisions of this province, are absolutely unrepresented in the Tertiary of the Great Basin. Fresh-water invertebrates are known sparingly in both regions, but the faunal sequence is far from satisfactory, while the characteristic simplicity of these forms reduces the possibilities of correlation. Land mammals are well represented in the Great Basin province and offer in their stages of evolution a satisfactory basis of correlation. They have been very rare, however, in the marginal marine areas.

Up to the present time, one of the most significant discoveries throwing light on the problem of correlation between the Pacific Coast and Great Basin provinces is the finding of a considerable number of remains representing land mammals in the marginal marine series of California. The collection was obtained by a

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party of advanced students from the University of California, in the North Coalinga region on the Western border of the San Joaquin Valley, in December, 1913. The expedition visited the Coalinga field under the leadership of Dr. Bruce Clark for the purpose of making a study of the sequence of invertebrate faunas, but the discovery of mammal remains seemed so significant that a large share of the work was devoted to examination of the vertebrate horizons.

For the material described in the following paper, the writer is indebted to all of the members of the University of California field party working in the Coalinga region in December, 1913. The first important specimens were obtained in the "Temblor" beds by C. L. Moody and J. M. Douglas. Later all of the members of the party collected at the locality visited by Moody and Douglas. A large part of the material secured at this locality was obtained by Neil C. Cornwall, who systematically excavated for mammalian remains in the soft sandstone and gravel. In the Jacalitos formation, the most important specimens were found by J. H. Ruckman, who worked very carefully over the basal portion of that formation. In the uppermost horizon, good material was obtained by all of the members of the party. The largest portion of this collection was secured by J. O. Nomland, who was making a special study of the Etchegoin. After the return of the December, 1913, expedition, Nomland made a second visit to the region and secured some of the most interesting material representing the latest fauna.

FAUNAL ZONES REPRESENTED

The vertebrate material obtained in the North Coalinga region represents at least four horizons or faunal zones. Collections were obtained: (1) in the "Temblor" phase of the Monterey series; (2) in the Jacalitos formation; (3) in the lower portion of the Etchegoin formation as mapped in this region by the University of California party in 1913; (4) a fauna later than that of the lower portion of the Etchegoin section, and obtained in the upper portion of the Etchegoin area.

The lowest horizon is characterized by abundance of horse teeth representing the genus *Merychippus*, and may be known as the Merychippus zone. From the Jacalitos horizon very few remains are known, and there does not seem to be sufficient characteristic material available to warrant final palæontologic designation. The lower Etchegoin horizon is characterized by the presence of *Pliohippus coalingensis*, and may be known as the Pliohippus coalingensis zone. The latest fauna is distinguished by a large specialized horse, with characters of *Pliohippus* and *Equus*, and by remains of a form near *Cervus*. It may be known as Cervus fauna.

The sequence of formations in the region examined is as follows:

Geological Periods	Local Formations	Vertebrate Faunas
Pleistocene	Terraces	
	Tulare	
		Cervus or Odocoileus
Pliocene	Etchegoin	Pliohippus coalingensis
		Pliohippus?
	Jacalitos	Neohipparion
	"Santa Margarita"	
Miocene	"Big Blue"	Merychippus californicus
	Monterey	Tetrabelodon?
	("Temblor")	Desmostylus hesperus
Oligocene	Lillis formation[1]	
Eocene	Tejon	
Cretaceous	Chico	

The following generalized section of the region examined by the field party in December, 1913, was prepared for the writer by J. H. Ruckman.

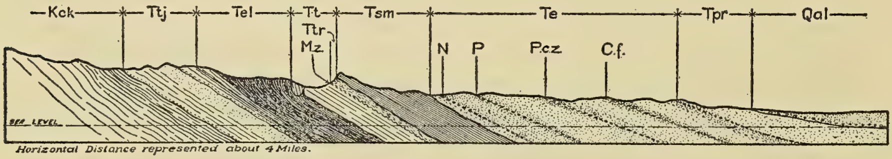


FIG. 1. Somewhat generalized east and west section across the North Coalinga horizons containing mammalian faunas. Section constructed by J. H. Ruckman. *Kck*, Cretaceous; *Ttj*, Tejon Eocene; *Tel*, Lillis formation, Oligocene; *Tt*, "Temblor"; *Ttr*, "Rainbow beds" or "Big Blue"; *M.z.*, Merychippus zone; *Tsm*, Santa Margarita; *Te*, Jacalitos and Etchegoin; *N*, Neohipparion locality; *P*, Pliohippus? locality; *P.c.z.*, Pliohippus coalingensis zone; *C.f.*, Cervus fauna; *Tpr*, Tulare formation; *Qal*, Pleistocene.

---

[1] From manuscript of J. H. Ruckman on North Coalinga section.

FAUNA OF MERYCHIPPUS ZONE

Occurrence

The vertebrate collection representing the Merychippus fauna was obtained in a zone at the upper limit of the formation known as "Temblor"[2] or "Vaqueros" about twelve miles north of Coalinga. The best exposures are at locality 2124 in SW. ¼, Sec. 28, T. 18 S., R. 15 E., M. D. B. & M.

The bones were found mainly in a zone of sandstone and conglomerate two or three feet thick immediately below the beds known as the "Big Blue," which overlies the characteristic "Temblor" beds. The zone containing bones consists in part of conglomerate, including pebbles ranging up at least to one inch in diameter. The upper portion of the zone is mainly fine sand. Fragments of bones and teeth have also been found scattered through the "Temblor" sandstone to a distance of at least one hundred feet below the conglomerate-sandstone zone in which the Merychippus fauna was obtained.

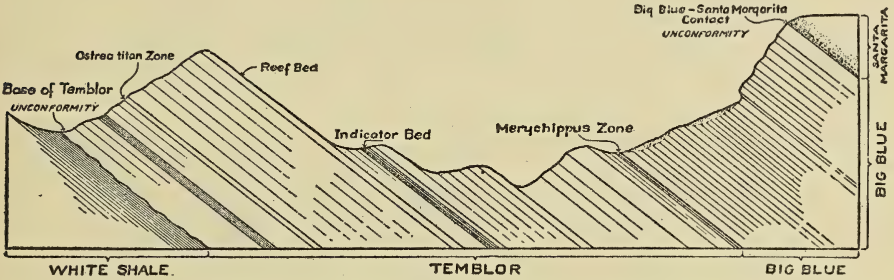


Fig. 2. Detailed section across the "Temblor" showing location of the Merychippus zone. Section prepared by C. L. Moody. Length of section approximately 1225 feet.

Question has naturally arisen as to the stratigraphic relation of the conglomerate and sandstone of the Merychippus zone to the "Temblor" beds below, and to the "Big Blue" above, as also regarding the relation of the "Big Blue" to the "Temblor."

The work of the University party in December, 1913, seemed to show a gradual transition from the "Temblor" beds through the Merychippus zone up at least to the base of the "Big Blue." At some localities there is an irregular contact between the conglomerate and the underlying "Temblor" sandstone, but such relief as was observed is possibly not more than should be expected in an estuarine deposit in which coarse sediments were moved at varying rates at different times. The general consensus of opinion of those members of the University party who examined this section was that no important stratigraphic break exists between the characteristic "Temblor" portion of the sequence and the top of the Merychippus zone.

---

[2] "Temblor" of F. M. Anderson, *Proc. Calif. Acad. Sci.*, 4th ser., vol. 3, p. 18, 1908. Correlated with the "Vaqueros" of Hamlin by Arnold and Anderson, U. S. Geol. Surv. Bull. 389, p. 87, 1910.

The beds north of Coalinga designated as the "Big Blue" were referred to by F. M. Anderson[3] as having the stratigraphic position of the Monterey series. Anderson stated that "their separation from the Temblor in the fields north of Coalinga is for convenience in logical treatment rather than for emphasis of their stratigraphic prominence."

Arnold and Anderson[4] mapped the "Big Blue" tentatively with the "Santa Margarita" but noted that it might really represent a part of the Monterey or a portion of the "Vaqueros" (p. 78). They called attention to its stratigraphic position corresponding to that of the Monterey (p. 76); to the probability that the line at its base may represent a great unconformity (p. 82); and to the overlap of the Tamiosoma zone upon it, indicating that it is a distinct unit (pp. 88 and 89).

In reporting on the Cantua-Panoche region north of Coalinga, after more careful study of the field than was possible in connection with the Coalinga report, Robert Anderson[5] states that in the area north of Coalinga mapped by Arnold and Anderson there is evidence indicating that the "Big Blue" belongs with the "Vaqueros." This evidence includes the presence in the "Big Blue" of marine fossils of early Miocene or "Vaqueros" type. Anderson suggests (p. 64) the possible equivalence of the "Vaqueros" of the Cantua-Panoche region to the lower portion of the Monterey shale in the region nearer the coast.

---

[3] Anderson, F. M., *Proc. Calif. Acad. Sci.*, 4th ser., vol. 3, p. 21, 1908.

[4] Arnold, R., and Anderson, R., U. S. Geol. Survey, Bull. 398, pp. 76, 78, 82, 88, 89; 1910.

[5] Anderson, R., U. S. Geol. Surv. Bull. 431–A, p. 65, 1910.

R. W. Pack, of the United States Geological Survey, who worked carefully over this region with Robert Anderson, states that the fauna of the marine beds below the "Big Blue" occurs also in sandy strata above the typical serpentinous shale, which forms the major part of the "Big Blue." This indicates that the time of deposition of the "Big Blue" belongs to the same biologic period as that of the "Temblor" or "Vaqueros" below, and that there was no great time interval between the deposition of the two.

Composition of the Merychippus Fauna

The material obtained in the Merychippus zone consists of scattered teeth and skeletal elements. No connected parts of the skeletons, and no teeth so closely associated as to indicate their certain reference to the same individual, have been found. The specimens were all obtained from coarse sands and gravels, presumably representing the wash upon a beach near the mouth of a river. The number of specimens secured exceeds that obtained at any other locality of this nature known to the writer in the Pacific Coast region. The occurrence at this place presumably indicates that when these beds were being deposited the land mammals found here were abundant in this region. It also indicates an unusual combination of circumstances making possible the preservation of these remains.

Associated with the remains of land mammals in the Merychippus zone are several specimens representing marine types. At least three species of sharks appear in this collection. At a level about two feet above the layer in which *Merychippus* teeth were most abundant, Mr. Cornwall obtained a perfectly preserved tooth of the sirenian, *Desmostylus*. As the remains of *Desmostylus* are characteristic fossils of the "Temblor" in this region, question has naturally arisen whether this tooth may not have been derived from the "Temblor" and secondarily deposited in the conglomerate at the base of the "Big Blue." Remains of *Desmostylus* are by no means abundant at any horizon, and it seems improbable that the occurrence of this tooth above the *Merychippus* stratum is the result of secondary deposition. It is probable that this animal was living in the sea in the period in which *Merychippus* inhabited the adjacent land.

The fauna obtained from the Merychippus zone includes the following forms:

Merychippus californicus, n. sp.
Prosthennops?
Procamelus?, sp.
Tetrabelodon?, sp.
Desmostylus, near *hesperus* Marsh.
Isurus, sp.
Carcharodon, sp.

MERYCHIPPUS CALIFORNICUS, n. sp.

Type specimen, $M\underline{1}$, no. 21247, locality 2124. From Merychippus zone between typical "Temblor" and "Big Blue."

Cheek-teeth of the *Merychippus* type, but tending to a more slender form than in *M. isonesus* of the Mascall Middle Miocene.

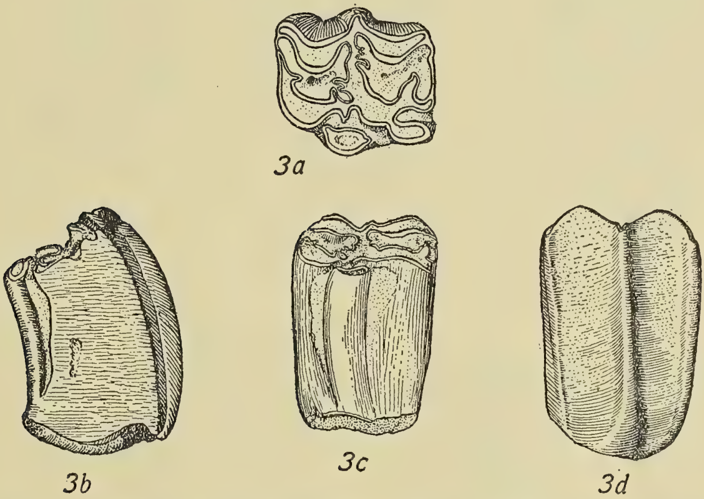
Remains representing Equidæ from locality 2124 comprise forty or fifty well-preserved upper and lower molars, several incisors, and limb elements including the calcaneum, astragalus, second phalanx, and a metapodial. The upper and lower molars seem all referable to a single species.

The characters of the upper molars (Figs. 3*a* to 8*b*) are in some respects similar to those of *Merychippus isonesus* of the Mascall Middle Miocene. The protocone is distinct from the protoconule and remains separate almost to the base of the crown. Only in very old, much worn teeth is there any suggestion of connection of the protocone and protoconule on the crushing surface. In cross-section, the protocone is round with a slight lateral compression. A ridge on the antero-external wall of the protocone reaches outward toward the protoconule, but does not unite with it until an advanced stage of wear is reached. The moderately complex folding of the enamel enclosing the fossettes approximates that of *M. isonesus*. In form and strength of the outer styles the Coalinga form is not appreciably different from typical Mascall specimens. Compared with *M. isonesus*, the upper molars from Coalinga show a tendency to be a little smaller in cross-section, and a little larger in length of crown. The type of upper molar seen here is that of a representative of *Merychippus* in the division of the group leading to *Hipparion*. In this group *M. isonesus* of the

Middle Miocene seems to be a less advanced stage and *M. calamarius sumani* of the Barstow Upper Miocene is more advanced.

The lower cheek-teeth (Figs. 9*a* to 11*b*) from Coalinga closely resemble *M. isonesus* in form and dimensions. The Coalinga specimens are possibly a little longer, but the difference is small. The metaconid-metastylid column is moderately flattened, and an antero-external ridge may be present on the protoconid.

Merychippus seversus, a form apparently widely distributed in the Mascall Miocene, is clearly separable from the Coalinga species by its much smaller size.

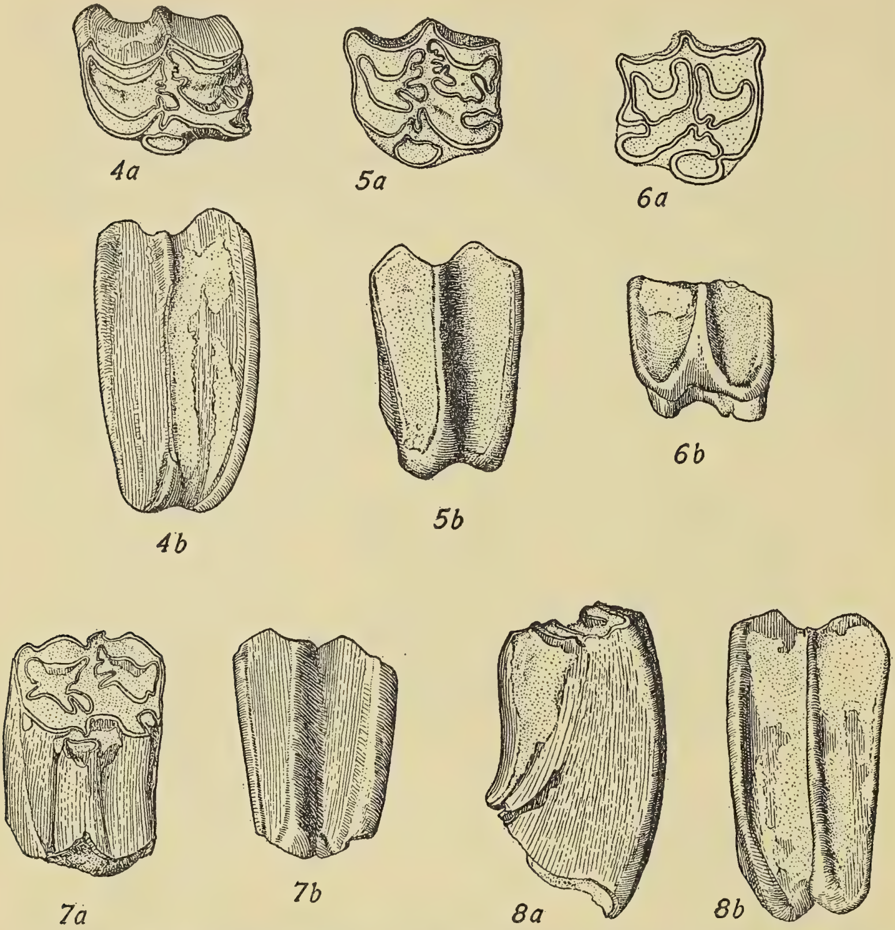


Figs. 3*a*–3*d*. *Merychippus californicus*, n. sp. M$\underline{1}$, no. 21217, natural size, Merychippus zone, North Coalinga region, California. Fig. 3*a*, occlusal view; Fig. 3*b*, posterior view; Fig. 3*c*, inner view; Fig. 3*d*, outer view.

Merychippus calamarius, a type abundantly represented in the Barstow Upper Miocene of the Mohave Desert, is larger and more advanced. One form, *M. calamarius sumani*, occurring rather rarely in the Barstow fauna approaches the combination of characters seen in the Coalinga specimens, but is a more advanced type, and is specifically separable.

Two incisor teeth (Figs. 12*a* to 13*b*) found with the Coalinga *Merychippus* fauna show deep invaginations of the enamel, and a thick cement deposit in the pits.

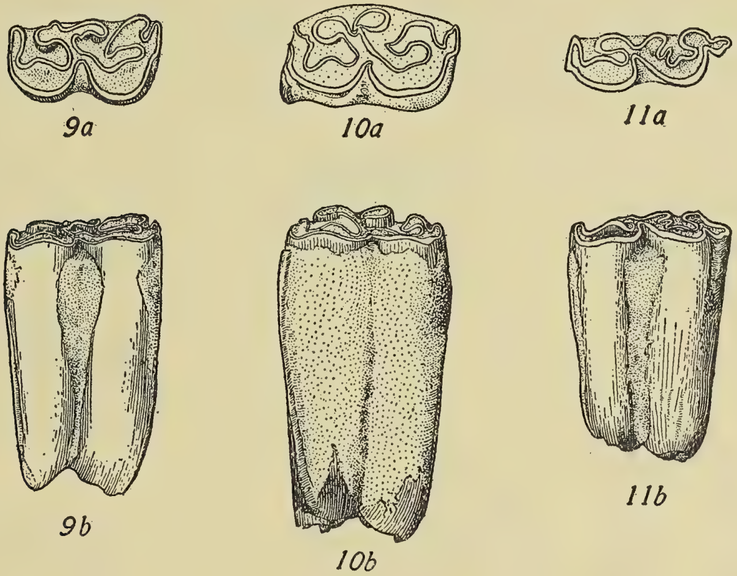
Of the protohippine limb elements (Figs. 14*a* to 14*d*) from locality 2124, a single calcaneum is slightly larger than those referred to *Merychippus* from the Mascall and Virgin Valley. It is of approximately the size of this element in *Merychippus calamarius* from the Barstow beds. An astragalus has dimensions approximately the same as the average *Merychippus* specimens from the Mascall



Figs. 4*a*–8*b*. *Merychippus californicus*, n. sp. Upper molars, natural size, Merychippus zone, North Coalinga region, California.

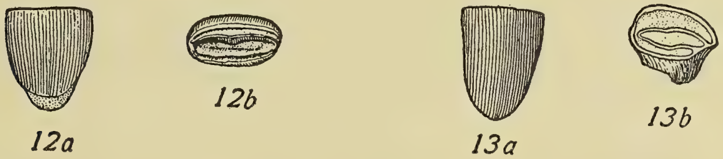
Figs. 4*a* and 4*b*, P$\underline{4}$, no. 21280; Fig. 4*a*, occlusal view; Fig. 4*b*, external view.
Figs. 5*a* and 5*b*, M$\underline{1}$, no. 21236; Fig. 5*a*, occlusal view; Fig. 5*b*, external view.
Figs. 6*a* and 6*b*, M$\underline{1}$?, no. 21241; Fig. 6*a*, occlusal view; Fig. 6*b*, external view.
Figs. 7*a* and 7*b*, P$\underline{4}$, no. 21230; Fig. 7*a*, occlusal and inner view; Fig. 7*b*, external view.
Figs. 8*a* and 8*b*, M$\underline{1}$, no. 21238; Fig. 8*a*, anterior view; Fig. 8*b*, external view.

and Virgin Valley. Another much worn specimen is considerably smaller and corresponds in size to the smallest available astragalus from the Mascall stage. The smaller astragalus is not as large as the smallest one known from the Barstow beds. The larger specimen slightly exceeds the dimensions of the smallest from the Barstow, but is considerably below the average size.



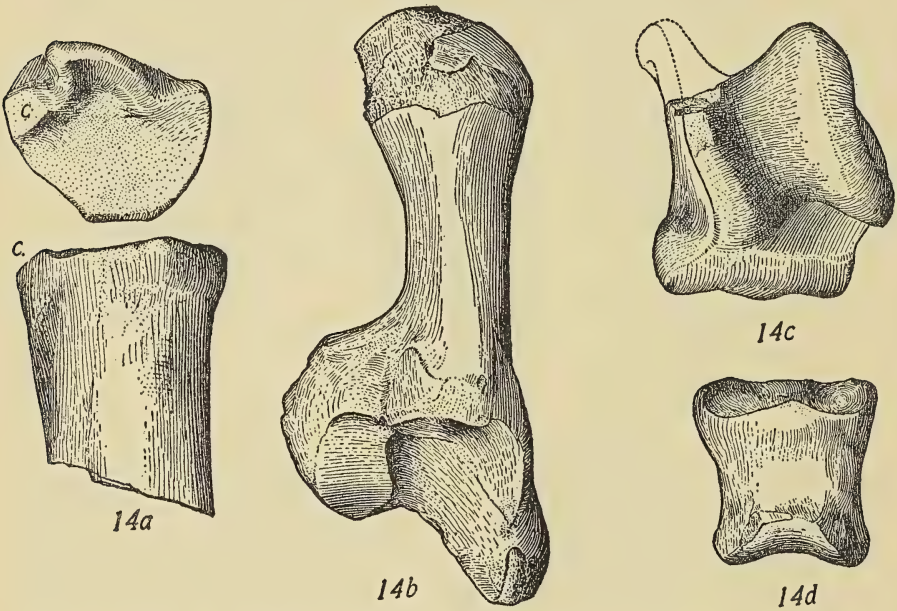
Figs. 9*a*–11*b*. *Merychippus californicus*, n. sp. Lower molars, natural size, Merychippus zone, North Coalinga region, California.

Figs. 9*a* and 9*b*, $P\bar{3}$, no. 21244; Fig. 9*a*, occlusal view; Fig. 9*b*, external view.
Figs. 10*a* and 10*b*, $P\bar{4}$, no. 21508; Fig. 10*a*, occlusal view; Fig. 10*b*, external view.
Figs. 11*a* and 11*b*, $M\bar{2}$, no. 21249; Fig. 11*a*, occlusal view; Fig. 11*b*, external view.



Figs. 12*a*–13*b*. *Merychippus californicus*, n. sp. Incisors, natural size. Merychippus zone, North Coalinga region, California. Figs. 12*a* and 12*b*, no. 21381; Fig. 12*a*, anterior view; Fig. 12*b*, occlusal view. Figs. 13*a* and 13*b*, no. 21374; Fig. 13*a*, anterior view; Fig. 13*b*, occlusal view.

A metatarsal III (Fig. 14*a*), no. 21509, from the Merychippus zone is of approximately the same size and form as the corresponding element in *Merychippus* specimens from the Mascall beds of Oregon. The Merychippus zone specimen is perhaps a little thicker anteroposteriorly. The facet for the cuboid is at least as large in no. 21509 as in the Mascall specimens, and is if anything a little nearer the plane of the ectocuneiform facet. The form of the proximal end of metatarsal III in no. 21509 can be matched almost exactly in *Merychippus* specimens from the Barstow fauna, but some of the Mohave specimens are larger and have a larger cuboid facet. The greatest transverse diameter of the proximal end is twenty-six millimeters.



14*a* 14*b* 14*c* 14*d*

FIGS. 14*a*–14*d*. *Merychippus californicus*, n. sp. Merychippus zone, North Coalinga region, California. All figures natural size. Fig. 14*a*, proximal end of metatarsal III, no. 21509, anterior and proximal views; *c*, cuboid facet. Fig. 14*b*, calcaneum, no. 21367, superior view. Fig. 14*c*, astragalus, no. 21368, superior view. Fig. 14*d*, second phalanx, no. 21366*a*, superior view.

The phalanges correspond in dimensions to those of the Mascall and Virgin Valley horses and are smaller than in the average *Merychippus* forms of the Barstow beds.

MEASUREMENTS OF CHEEK-TEETH[6]

All measurements of anteroposterior and transverse diameter were taken about ten millimeters above the base of the crown.

Height of crown as given is the greatest height measured along the mesostyle of upper teeth or along the hypoconid of lower teeth.

	No. 21250 $\mathrm{P}\underline{2}$	No. 21326 $\mathrm{P}\underline{3}$	No. 21240 $\mathrm{P}\underline{4}$	No. 21239 $\mathrm{P}\underline{4}$	No. 21238 $\mathrm{M}\underline{1}$	No. 21236 $\mathrm{M}\underline{1}$	No. 21237 $\mathrm{M}\underline{1}$	No. 21246 $\mathrm{M}\underline{3}$
Anteroposterior diameter..	21 mm.	20.3	17.8	19	17	18.3	19	15.2 with cement
Transverse diameter......	18	*a*21	*a*20.5	20.8	21	20.2	19.9	17.7 with cement
Height of crown.........	22.5 worn	35.5	36	27 worn	37.4	25.9 worn	28.5 worn	29.5

	No. 21325 $\mathrm{P}\overline{2}$	No. 21245 $\mathrm{P}\overline{3}$	No. 21508 $\mathrm{P}\overline{4}$	No. 21249 $\mathrm{M}\overline{2}$	No. 21324 $\mathrm{M}\overline{3}$	No. 21329 $\mathrm{M}\overline{3}$
Anteroposterior diameter...........	20 mm.	19.3	21.2	16.7	20.5	21.5
Transverse diameter................	9.9	10.2	10.4	9	7.5	*a*8
Height of crown....................	16.5 worn	33.7	38.8	28.5	21.5 worn	33.4

PROSTHENNOPS?, sp.

A single lower molar (no. 21511, Figs. 15*a* and 15*b*) from the Merychippus zone represents a peccary near *Prosthennops*. The tubercles are low and less acute than in *Bothriolabis* of the John Day.

MEASUREMENTS OF No. 21511

	mm.
? $\mathrm{M}\bar{2}$, greatest anteroposterior diameter..................................	14.5
? $\mathrm{M}\bar{2}$, greatest transverse diameter..	11.4

PROCAMELUS?, sp.

The remains referred tentatively to *Procamelus* (Figs. 16 to 18) consist of several somewhat worn astragali, a portion of a calcaneum, a fragment of the distal end of a metapodial, a proximal phalanx and an upper molar. These specimens are near the size and dimensions of *Procamelus* forms from the late Miocene. The proximal phalanx (no. 21343) is much larger than that of the Recent llama. It is like that of *Procamelus*, but is larger than in some forms in the later Miocene. The astragali are a little larger than in the Recent llama, and smaller than in many specimens of *Procamelus*. An astragalus from locality no. 2028, in the Cedar Mountain region of Nevada, is similar in form, but a trifle larger. The astragali (no. 21344 especially) are almost identical in form with certain small cameloid astragali from the Upper Miocene of the Mohave Desert which are tentatively referred to *Procamelus*.

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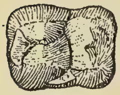
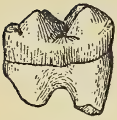
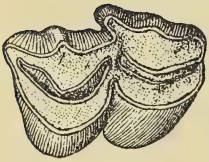
[6] For method of measurement see Univ. Calif. Publ. Bull. Dept. Geol., vol. 7, p. 409, 1913.


15a


15b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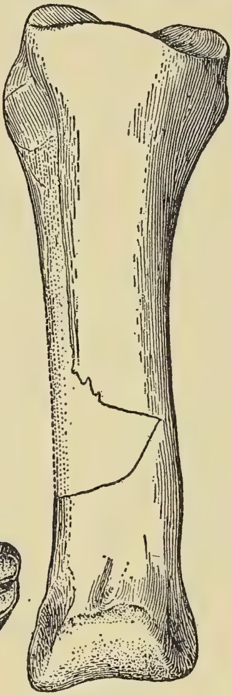
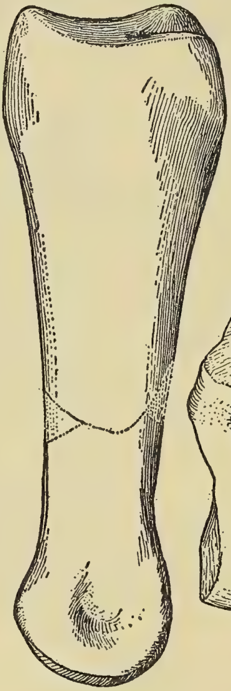
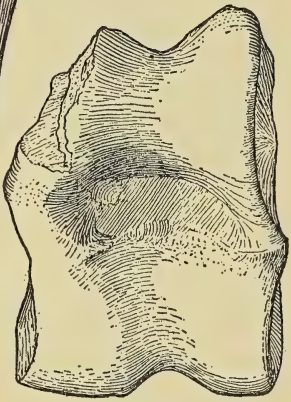

17a


17b


18

Figs. 15*a* and 15*b*. *Prosthennops?*, sp. M$\overline{2}$?, no. 21511, natural size. Merychippus zone, North Coalinga region, California.

Figs. 16–18. *Procamelus?*, sp. Merychippus zone, North Coalinga region, California. All figures natural size. Fig. 16, M$\underline{2}$, no. 21510, occlusal view. Figs. 17*a* and 17*b*, proximal phalanx, no. 21343; Fig. 17*a*, superior view; Fig. 17*b*, medial view. Fig. 18, astragalus, no. 21344, superior view.

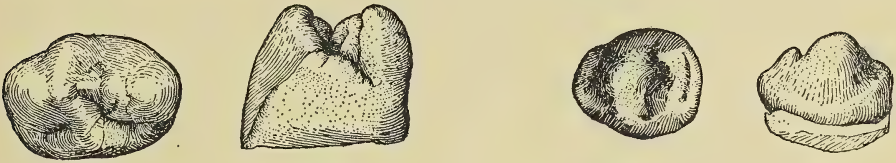
A single upper molar tooth, no. 21510, constitutes the only representation of the dentition.

Measurements of Upper Molar No. 21510

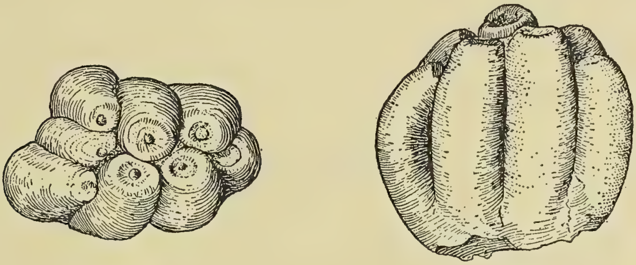
	mm.
? M$\underline{2}$, greatest anteroposterior diameter	26.2
? M$\underline{2}$, greatest transverse diameter	15.9

TETRABELODON?, sp.

A considerable number of fragments represent a proboscidean near *Tetrabelodon* (Figs. 19*a* to 20*b*). The only complete tooth is a milk molar. Though certain generic determination does not seem possible, the absence of all proboscidean remains from beds older than Middle Miocene in America makes these specimens of importance in determining the epoch that this fauna could be presumed to represent.



Figs. 19*a*–20*b*. *Tetrabelodon?*, sp. Cheek-teeth, × ½. Merychippus zone, North Coalinga region, California. Figs. 19*a* and 19*b*, occlusal and end view of fragment of cheek-tooth no. 21366. Fig. 20*a*, occlusal view of milk molar no. 21377; Fig. 20*b*, lateral view of specimen 21377.



Figs. 21*a* and 21*b*. *Desmostylus*, near *hesperus* Marsh. M$\underline{1}$, no. 21375, × ½. Merychippus zone, North Coalinga region, California. Fig. 21*a*, occlusal view; Fig. 21*b*, lateral view.

DESMOSTYLUS, near HESPERUS Marsh

Two well-preserved cheek-teeth, an upper molar (Figs. 21*a* and 21*b*), and a lower molar, represent *Desmostylus*, the peculiar sirenian now known to have ranged widely around the North Pacific in Middle Tertiary time. In an earlier article[7] the writer has assembled all available information relating to *Desmostylus*, with the result that the best known occurrences seem to fall in the zone of the "Temblor" or "Vaqueros" of California. Other occurrences are apparently near that horizon. If the vertical range of this form is not unusually long, the wide geographic range through marine deposits of the North Pacific gives us an almost unprecedented opportunity for correlation, as the horses with which *Desmostylus* occurs in these beds have a wide geographic range over the land.

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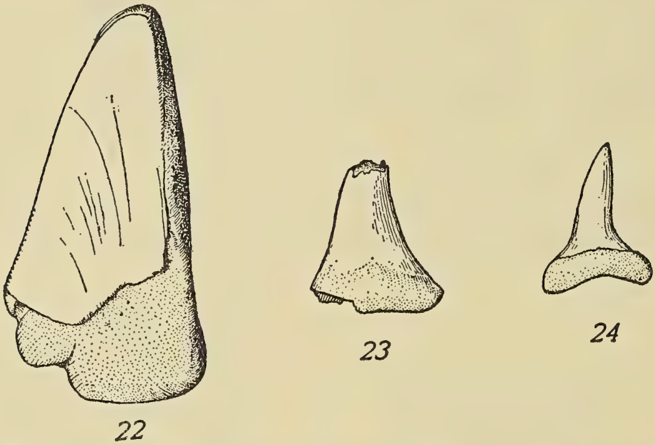
[7] Merriam, J. C., Univ. Calif. Publ. Bull. Dept. Geol., vol. 6, pp. 403–412, 1911.

SELACHIAN TEETH

Three types of shark teeth from the beds at locality 2124 represent forms corresponding approximately to species occurring in strata referred to the "Temblor" horizon of middle and southern California. One specimen (Fig. 22) is a fragment of a *Carcharodon* tooth from which the denticles have been removed by wear in shifting about in the sand before final burial. A second worn specimen (Fig. 23) is evidently a form of *Isurus*; a third (Fig. 24) is a worn *Lamna* or an *Isurus*.



Figs. 22–24. Selachian teeth from the Merychippus zone, North Coalinga region, California. All figures natural size.

Fig. 22. *Carcharodon*, sp. no. 21563.
Fig. 23. *Isurus*, sp. no. 21565.
Fig. 24. *Isurus?*, sp. no. 21564.

Stratigraphic and Palæontologic Correlation of the Merychippus Zone

The appearance of a *Merychippus* fauna in the essentially marine section of the California area is of significance with respect to the broad problem of time relations of the West-American Tertiary. In considering the meaning of this occurrence, it is desirable: *first*, to determine as certainly as possible the position of the Merychippus zone in the marine section of the California area and to ascertain the basis for determination of age of this particular member of the California marine series; *second*, to determine the relation of the Merychippus fauna to those in the mammalian sequence of America, and the time relations of the American mammalian series to the succession in typical sections of the Old World.

Position of Merychippus Zone in the California Marine Series.—As has been shown in the general discussion of occurrence of the Merychippus fauna, the evidence indicates that this zone is included within a portion of a series designated as "Temblor" by F. M. Anderson and referred to as "Vaqueros" in all recent accounts of this region published by members of the United States Geological Survey. The strata referred to the "Temblor" or "Vaqueros" of the North Coalinga field are evidently a part of a wide-spread series of deposits generally recognized as representing one great period of sedimentation and designated as the Monterey series.[8]

In the earliest attempt at separation of faunal zones in the section between the Tejon Eocene and the San Pablo Miocene the writer[9] contrasted the fauna of the lowest portion of the beds referred to the Monterey series in the Contra Costa Hills with that of higher members of that section, exclusive of the contrast between sandstone and shale members due to varying conditions of deposition. The faunal zone of the lowest beds above the Tejon Eocene of the Contra Costa Hills was designated the Agasoma gravidum zone, and was considered as Lower Miocene. This fauna was compared with that of beds presumed to be of Lower Miocene age in the southern part of the state. Two faunal assemblages from the southern area were referred to the Lower Miocene. One assemblage, characterized by the presence of *Turritella ocoyana* and a number of *Agasoma* species, was referred to as the Turritella ocoyana zone. The other fauna, characterized by *Turritella inezana* and an *Agasoma*, was distinguished as the Turritella (hoffmani) inezana[10] zone. It was suggested that these zones did not represent the same horizon, but that they were not widely separated. The ocoyana zone was shown to have a fauna of more recent aspect than that of the inezana zone. The *Agasoma* forms of the ocoyana zone were described as in some respects intermediate between *Agasoma gravidum* of the Contra Costa Hills, and *Agasoma sinuatum*, a species from the upper portion of the Contra Costa Hills section.

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[8] Lawson, A. C., Univ. Calif. Publ. Bull. Dept. Geol., vol. 1, pp. 1–59, 1893. See also Louderback, G. D., Univ. Calif. Publ. Bull. Dept. Geol., vol. 7, pp. 177–241, 1913.

[9] Merriam, J. C., Univ. Calif. Publ. Bull. Dept. Geol., vol. 3, pp. 377–381, March, 1904.

Following shortly after the faunal separation of the Agasoma gravidum zone, Hamlin[11] described as the "Vaqueros formation," a section containing the fauna of the Turritella inezana zone. Later, from the southern part of the state, F. M. Anderson[12] described as the "Temblor formation" an important series of strata representing in part at least the Turritella ocoyana zone.

F. M. Anderson and Arnold and Anderson have considered the "Vaqueros" of Hamlin and the "Temblor" of F. M. Anderson as practically representing the same stratigraphic and faunal unit. Arnold and Anderson, by virtue of their decision as to the stratigraphic identity of the deposits containing these two faunas, have used the name "Vaqueros"[13] as having precedence in use over "Temblor." F. M. Anderson,[14] also holding that the two zones represent the same stratigraphic unit, considers the description of the "Vaqueros" presented by Hamlin as insufficient. In reality the description by Fairbanks, based on a typical section, precedes that of Hamlin and establishes the name.

The most recent investigations of the stratigraphic, geographic, and faunal relations of the Turritella inezana and Turritella ocoyana zones seem to the writer still to suggest that these zones may represent recognizable stages in the evolution of the Tertiary marine faunas of the California area, and that there is a possibility of stratigraphic separation of the two. Under the circumstances, the writer is inclined to continue his use of the faunal designations of these horizons suggested in 1904. If the faunal separation is continued, and if the stratigraphic relations are not clear, it seems desirable to use for geologic reference to the strata containing these faunas terms which suggest their geographic occurrence. The writer is therefore inclined for the present to use the name "Vaqueros" for the series of strata containing the *Turritella inezana* fauna. The name "Temblor" is tentatively used for those sections in the southern part of the state containing the *Turritella ocoyana* fauna, on the presumption that this part of the series may be stratigraphically distinct from the "Vaqueros." It is probable that the "Temblor" as thus designated is really a part of the Monterey series as now recognized.

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[10] *Turritella hoffmani* Gabb has been shown by Arnold to be identical with the previously described *T. inezana* of Conrad.

[11] Hamlin, H., U. S. Geol. Surv. Water Supply Paper No. 89, distributed June 15, 1904. Hamlin's use of name preceded by H. W. Fairbanks, U. S. Geol. Surv. Folio 101, distributed June 10, 1904.

[12] Anderson, F. M., *Proc. Calif. Acad. Sci.*, 3d ser., Geol., vol. 2, p. 170, 1905.

[13] Arnold, R., and Anderson, R., U. S. Geol. Survey Bull. 398, p. 87, 1910.

[14] Anderson, F. M., *Proc. Calif. Acad. Sci.*, 4th ser., vol. 3, pp. 38 and 39, 1908.

In a recent discussion of the geologic range of Miocene faunas of California, Professor James Perrin Smith[15] has taken the view that the "Temblor" fauna was synchronous with that of the Monterey, and that the Turritella inezana zone represents a horizon below the typical Monterey. The name "Vaqueros" is used by Professor Smith for the beds containing the *Turritella inezana* or "Vaqueros" fauna.

The available evidence indicates that the Merychippus zone occupies a position within the "Temblor," and presumably some distance below the upper limit of the Monterey series. If the beds of this zone were considered unconformable upon the "Temblor," they would presumably correspond in time equivalence to some portion of the upper Monterey beds as represented in middle California. The "Big Blue" resting above the Merychippus zone is separated by marked unconformity from the "Santa Margarita" above it. The "Santa Margarita" of the Coalinga region, according to Dr. Bruce Clark,[16] contains a fauna closely similar to that of the middle San Pablo. The unconformity between the "Santa Margarita" and "Big Blue" apparently marks a long period, which probably represents a time sufficiently long to equal the period of deposition of the earlier portion of the San Pablo.

Age of the Monterey.—During several decades past the Monterey series has been considered as Miocene and strata containing a faunal assemblage of the stage seen in the "Temblor" of the

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[15] Smith, J. P., *Proc. Calif. Acad. Sci.*, 4th ser., vol. 3, pp. 164, 165 and 169, 1912.

[16] Clark, B., Unpublished manuscript on the Fauna of the San Pablo Miocene.

Coalinga region have been generally recognized as Lower Miocene. In actual practice the determinations of age of strata referred to the Miocene have never been based on very extensive or exact comparisons.

In describing a collection of fossils from Astoria in 1849 Conrad[17] expressed his view as to age determination of fossiliferous deposits as follows:

> ". . . the forms are decidedly approximate to those of the Miocene period which occur in Great Britain and the United States. *Nucula divaricata*, for instance, closely resembles *N. Cobboldiæ* (Sowerby) of the English Miocene, and *Lucina acutilineata* can scarcely be distinguished from *L. contracta* (Say), a recent species of the Atlantic Coast and fossil in the Miocene beds of Virginia. *Natica heros*, a shell of similar range, is quite as nearly related to the *N. saxea*. A similar number of species might be obtained from some of the Miocene localities of Maryland or Virginia and yet no recent species be observed among them. In the Eocene, and also in the Miocene strata, there are peculiar forms which obtain in Europe and America, and although the species differ, yet they are so nearly allied that this character alone, independent of the percentage of extinct forms, is quite a safe guide to the relative ages of remote fossiliferous rocks. On this foundation, I speak with confidence, when I assign the fossils of the Columbia River to the era of the Miocene."

In one of the first references to the Miocene of California, Conrad,[18] in speaking of beds at Santa Barbara, called Miocene, expresses the following view as to the age of the strata:

> "The *Mercenaria* and *Pecten* are closely related to species of the Virginia Miocene, and indeed there is an extraordinary analogy in all of the above mentioned shells to species of the Atlantic Miocene deposits. . . ."

Discussing the age of fossil-bearing deposits in California in 1857 Conrad[19] makes the following statement:

> "Like the Miocene of Virginia, the Estrella group is characterized by large and even comparatively gigantic species of Pectinidæ, so unlike any living on the coast of California or the Atlantic states. It would seem that this family had then reached their maximum of development and the genus *Pallium* was first introduced, and of far larger size than any which now exists. It is worthy of remark that the generic character is developed on a far grander scale than appears in sub-

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[17] Conrad, T. A., U. S. Exploring Expedition, 1849, p. 659 (see original reference, *Am. Jour. Sc.*).

[18] Conrad, T. A, *Proc. Acad. Nat. Sc. Philad.*, vol. 7, p. 441, 1834.

[19] Conrad, T. A., Pacific Railroad Survey, vol. 7, p. 189, 1857.

sequent epochs, the prominent teeth and thick hinge reminding us of the genus *Spondylus*.

"Every new collection of Miocene fossils shows more clearly the connection between some of the Tertiary strata of California and those of Virginia. The species in the present collection are far more interesting than in others of the same formation on the Pacific slope which I have yet seen. It does not appear that this group of fossils has any living representative in the present fauna of the Pacific Coast, but several of them approximate to extinct Virginia species; and I am not sure that the large *Pecten magnolia*, herein described, is not identical with the Virginia species *P. jeffersonius*.

"I think it might safely be assumed that the San Rafael Hills, Santa Inez Mountains and Estrella Valley contain strata which are parallel to Miocene sands and clays of the James and York rivers in Virginia."

Later writers have generally followed the lead of Conrad in fixing the age of middle Tertiary strata, including the Monterey. In an early description of the type locality of the Monterey, Blake[20] simply refers to it as Tertiary. In the description of these beds by Lawson[21] the statement is made that characteristic Miocene fossils have been found in the Monterey series at various parts of the coast by former observers, and in particular at the town of Monterey. A list of species obtained from a locality near Carmelo Bay, and determined by W. H. Dall, is published in Professor Lawson's paper.

In recent years, the results of work on the Tertiary of California have brought to light previously unknown thicknesses of strata, new and important unconformities indicating large gaps in the record, and new faunal zones intercalated between those previously known. The addition of these factors, which lengthen the geologic record, has placed in the division recognized as Miocene time an unexpectedly long series of events, and has very naturally raised a question whether the lowest beds referred to the Miocene do not represent Oligocene. In a discussion of the geologic range of *Desmostylus*,[22] a sea-cow, in 1911, the writer described this form as most common in beds called Lower Miocene of the southern part of the state, and suggested that the beds marking its downward limit of geologic range might correspond to Oligocene.

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[20] Blake, W. P., Pacific R. R. Report, vol. 5, chapter 13, 1856.

[21] Lawson, A. C., Univ. Calif. Publ. Bull. Dept. Geol., vol. 1, p. 27, 1893.

[22] Merriam, J. C., Univ. Calif. Publ. Bull. Dept. Geol., vol. 6, p. 407, 1911.

Recently Arnold[23] and Hannibal, in a classification of the Tertiary formations of the Pacific Coast region, have stated that the "Monterey . . . as far as our present knowledge goes, might be placed equally well in the latest Oligocene or the earliest Miocene on the basis of the general faunal facies."

Though practically all determinations of the age of marine Tertiary formations in California have been based upon palæontologic correlation, the true basis of comparison of these horizons has never been clearly expressed. The determinations were made either by very general correlation with determined faunas of eastern United States and Europe, or by use of the Lyellian percentage method.

The comparisons of West Coast faunas of post-Eocene age with those of the Atlantic area, upon which the original age determinations of Conrad and Gabb were based, were made at a time when the faunas of the Atlantic area were not as well known as at present, and the study of the Pacific Coast faunas was hardly begun. The results of a thorough comparison with the Atlantic faunas are not available to us as the basis for a fully satisfactory judgment from this point of view.

In connection with a recent study of the marine Tertiary of the Washington-Oregon area, Arnold and Hannibal[24] express the opinion that "a direct correlation between the Pacific Coast marine Tertiary and the deposits of Europe and bordering the Gulf of Mexico is impossible owing to almost total absence of identical species except in the Eocene." In consideration of possible correlation of strata of the Pacific Coast region with those of the Oligocene of Europe, attention is called to the fact that there do not appear to be any marine forms that will serve as a basis for direct comparison. The suggestion is, however, made that an Oligocene facies is indicated by absence of all Recent molluscan species from the older strata considered as post-Eocene, and the gradual addition of a small percentage of Recent species in the Monterey. The presence of certain Eocene-Oligocene genera as *Crassitellites*, *Aturia*, etc., also suggests Oligocene age.

A number of age determinations of Pacific Coast Tertiary formations have been based upon use of the percentage method, and while fairly consistent results were secured, it must be borne in mind that determinations obtained by this means may be subject to modification by several factors. It is, for example, evident that since the time of Lyell views as to the limits of species have greatly changed, and the percentages used for the species of Lyell's day would not apply with the same result upon the same faunas with present-day limitations of species. Species as now defined are much more closely restricted in range of characters. This limitation of the characters in specific groups has naturally restricted also the geographic and geologic range. Studies in the general accuracy of percentage method age-determinations recently made by Bruce Martin at the University of California have shown surprisingly large errors from various sources in ordinary computations, unless a very full representation of the fauna is available.

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[23] Arnold and Hannibal, H., *Proc. Amer. Phil. Soc.*, vol. 52, p. 575, 1913.

[24] Arnold, R., and Hannibal, H., *Proc. Amer. Philos. Soc.*, vol. 52, p. 574, November–December, 1913.

Aside from purely palæontologic determinations of the age of Tertiary formations in the California area, we have practically nothing as a basis for definition of historic stage in comparison with the later portion of geologic history in other parts of the world. Though every one admits the exceeding desirability of some method of comparison connected solely with a study of crustal movements, scarcely any attempt has been made to apply such a means of determination for stratigraphic units of this region older than the close of the Pliocene. Presuming that we have in the Pleistocene a satisfactory medium of comparison through crustal movement, without reference to climatic and faunal characters which are commonly the means of correlation employed, there seems no satisfactory method of comparison for systems older than Pleistocene other than by approximate matching of unconformities.

The California Tertiary geologic sequence is notoriously complicated. Crustal movements have been frequent; unconformities are common; and it is difficult to see how any one working in California geology up to the present time could have selected the particular unconformities or determined the movements needed to give us the key to comparison of our Tertiary history with that of eastern United States or of Europe. At any rate, this has not been done with any assurance of accuracy. At best there could be nothing more than a rough approximation based on the assumption that some of the diastrophic events here have a definite relation to those that have occurred elsewhere.

A general consideration of the present situation with reference to determination of age of the members of the California Tertiary sequence makes it evident that our present determinations are not based on thoroughly satisfactory studies in any of the several possible fields of endeavor, and that much work may profitably be given to an examination of this problem.

Position of the Merychippus Fauna in the Mammalian Sequence of America.—In terms of the vertebrate series of western North America, the fauna of the Merychippus zone in the North Coalinga region is clearly later than Lower Miocene, and not later than Upper Miocene. Proboscidean remains are not certainly known in America at a horizon lower than Middle Miocene. The widespread genus *Merychippus* is not known earlier than Middle Miocene, and the characteristic forms of that genus in the Middle Miocene of America are not more advanced than the species of the Merychippus zone in the Coalinga region. The number of horse remains found gives ample opportunity to determine the stage of evolution of the cheek-tooth dentition, and it seems scarcely possible that there could be any misunderstanding as to the stage in the history of this group represented here. The available material representing camels does not suggest an age determination different from that based on the representatives of the horse and mastodon groups.

Whatever may be the relation of the divisions of the American continental Miocene fauna or formation sequence to the sequence of the Old World based upon the succession of mammalian forms, it seems clear that the Merychippus zone of the Coalinga region is near the stage of the Great Basin Middle Miocene fauna represented in the Mascall of eastern Oregon and the Virgin Valley of the northern Nevada region. Through the medium of comparison with the Great Basin sequence, there is justification for correlating the stage of the Merychippus zone approximately with that of the Pawnee Creek beds of northeastern Colorado and other occurrences of beds referred to Middle or late Miocene in Western North America.

The only means of escape from the conclusions stated above as to relative age of the Coalinga *Merychippus* fauna would presum-

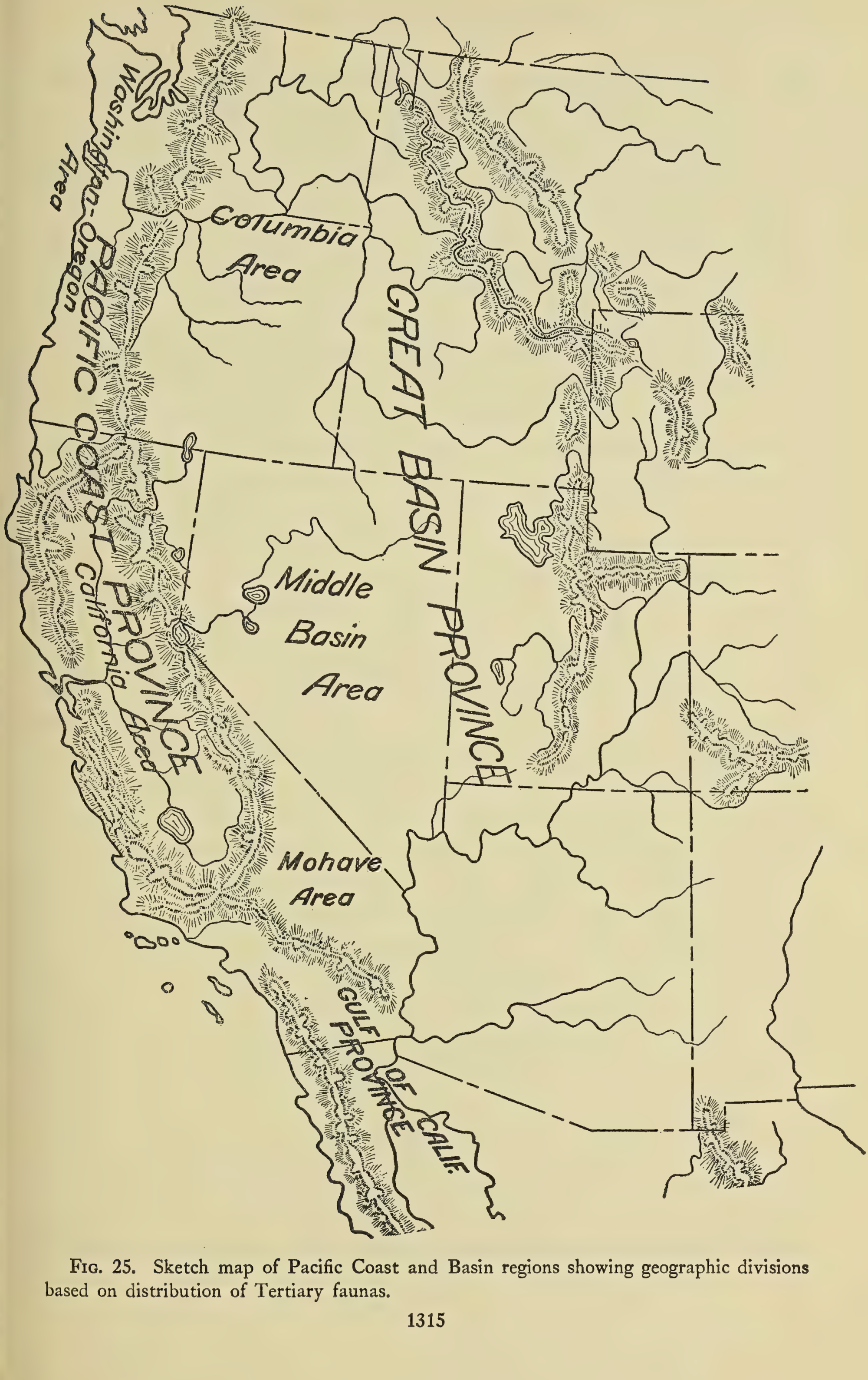

Fig. 25. Sketch map of Pacific Coast and Basin regions showing geographic divisions based on distribution of Tertiary faunas.

ably be reached through consideration of the possibility that the fauna of the California Merychippus zone originated west of the Wasatch, or that it first appeared in California or possibly in the Great Basin and remained in the extreme west for some time before migrations populated the Great Plains area.

The presence of a form of the mastodon type in the Coalinga Merychippus zone may suggest the possibility that this fauna represents the earliest appearance in America of Old World immigrants not known until considerably later in the region to the east. While it is possible that Asiatic forms colonizing America followed the west coast of the continent south to California, it is unsafe to consider this as necessarily the most inviting path for migration. Other routes leading into the Great Plains region may have been easily accessible. Aside from the California specimens under consideration here, the oldest American representatives of the mastodon group are found in formations situated to the east of the eastern boundary of the Great Basin.

The *Merychippus* group evidently originated in America. The Equidæ were largely represented here in late Oligocene time, and were unrepresented at that stage in the Old World so far as known. Unfortunately for consideration of the possibility of western origin of *Merychippus* types, we have, as yet, no representation of the mammalian fauna of the Great Basin province between the close of the John Day Oligocene and the beginning of the Middle Miocene. As nearly as can be judged, this interval represents a long period. During the earlier portion of this time the John Day beds were subjected to erosion. In the latter part of the interval the Columbia Lava accumulated in the northern portion of the province, and great rhyolite outbursts seem to have occurred in the Middle Basin area. It seems that the Great Basin province may have been a region with somewhat varied relief in which no extensive accumulation of deposits occurred during the first part of the Lower Miocene, and was widely covered with lava flows in the second part of this epoch.

As *Merychippus* is an animal with tooth and foot structure better adapted to grazing and to plains-living than the known American Lower Miocene horses, it possibly developed in the Great Basin on wide stretches of plains in early Lower Miocene, or on the great lava plains of late Lower Miocene. So far as environmental conditions have influence in the evolution of specializing types, one might expect to find such a form as *Merychippus* arising in response to the stimulus of environment on the considerably greater areas of the Great Plains country farther to the east, rather than in the Great Basin.

The further possibility is available that *Merychippus* originated in Lower Miocene time on the extreme western border of the continent, in California.

According to the view that the greatest number of new progressive forms will arise on the largest continental masses, one almost unavoidably considers the middle of the continent as the locus of evolutionary or creative activity. This is true mainly in the sense in which the center of gravity of any mass is the controlling point. It may be that temporarily isolated marginal areas bordering large land masses furnish at least as satisfactory points of origin or nurseries of new forms as could be provided by any set of conditions on other portions of a large land mass, and possibly the California region has been favorably conditioned for inducing the development of new types of mammals.

The California area, as it appears today, offers on the plains of the Great Valley an unusual combination of conditions which might well be favorable to production of a new type of horse. In the time of deposition of the Merychippus zone of Coalinga, a large part of the Coast Range region and the southern end of the Great Valley were under water, and the degree of isolation conditioned by the Sierra boundary was probably less marked than at the present day. For a considerable time preceding the deposition of the Merychippus zone, conditions were not materially different from those during the deposition of the beds at that horizon. Somewhat earlier the land area was larger. The conditions do not, however, seem to have been as favorable for the development of the *Merychippus* group in this area as they probably were in many other regions. At least, there is no special warrant for supporting the hypothesis that California was the point of origin of this group.

On the whole, the evidence indicates that the fauna of the Coalinga Merychippus zone is at least as advanced as that of the Mascall and Virgin Valley formations of the Great Basin; and that there is no reason for assuming that California was the place of origin of this group. It also appears that the Mascall and Virgin

Valley faunas are not younger than the stage of evolution of assemblages considered to represent the Middle Miocene of the areas to the east, and that there was probably close faunal connection with the region to the east. The Middle Miocene fauna of the Great Basin evidently represents approximately the same period as that of other areas farther to the east. There is no reason for believing that the Great Basin fauna in general or the *Merychippus* group in particular necessarily originated in this region. A portion of the fauna derived from Asiatic immigration may have appeared here before it reached the Great Plains area, but the chances are against its having been largely represented here before it was known elsewhere on the continent. The possible Californian or Great Basin origin of Miocene groups should not be overlooked in further consideration of the Pacific Coast faunas, but it is improbable that the geographic provinces were so sharply separated in early Miocene time that a group of the *Merychippus* type could become widely spread in the Great Basin and Pacific Coast provinces and remain unrepresented east of these regions.

Relation of American Miocene Mammal Horizons to Those of the Old World.—In correlating marine Middle Tertiary faunas of western North America with those of Europe, it is difficult to make direct comparisons, as the North Pacific Ocean was connected with the marine area bordering Europe only by circuitous routes, or by paths leading through zones of widely varying temperatures. For this reason, one might expect to find relatively little correspondence, excepting in similarity of stage of evolution of forms surviving from faunas common to both regions at some earlier period. There is little known in the comparative history of marine life suggesting migration of faunas between these areas in middle Cenozoic time to such an extent as to leave a distinct impression.

In a comparison of the history of the mammalian fauna of North America with that of the Old World, one might expect to find that the grouping of continents around the North Pole has permitted moderate crustal movements to bring about occasional union of those land masses, and that this connection of the areas would invite faunal mingling.

In the critical regions where connection and separation of the continental areas might be expected, especially the Alaskan-Siberian region, there is evidence of varying position of land and water, suggesting alternations of union and separation of the land areas. Whatever inhibitive influence might be exerted by an arctic climate, such as that of the present day, was largely eliminated throughout the greater part of Tertiary time, as the earth climate was somewhat warmer than at present, and the polar regions did not present an insuperable temperature barrier.

In the Tertiary history of mammalian faunas in the Northern Hemisphere, we note certain epochs marked by similarity of life over nearly the whole region. These epochs alternate with times of development of provincial faunas. Without calling in the suggestion of independent origin of similar types in different regions too frequently to satisfy the law of probability, it is difficult to account for these recurrences of similar faunas unless we accept the view that they have been induced by crustal movements uniting and separating land areas, and also closely related to or concurrent with considerable climatic variation. The opportunity for intermigration of faunas on the land areas concerned appears on the whole better than in the case of marine life in the bordering seas, as the path of emigration was shorter and involved less range of latitude. Other factors being approximately even, in a study of the Tertiary of the Northern Hemisphere, one might expect more satisfactory results in correlation based on comparative studies in the history of land mammals than in comparison of marine invertebrates.

Through the combined work of many investigators, and especially by the comparatively recent assembling of all results in this field by Osborn, Matthew, Scott, Schlosser, and others, it is evident that the portion of Tertiary time, including Oligocene, Miocene, and Pliocene, is actually marked by important intermigrations of land mammals between America and Eurasia. Within this time, the early Oligocene is characterized by appearance of similar forms in North America and in the Old World. In late Oligocene, intermigration seems less marked. In Middle Miocene the movement is particularly noticeable again, especially in the first certain appearance in America of the proboscideans, the teleocerine rhinoceroses, and probably several carnivore groups. In later Miocene and Pliocene time, the number of common forms increases considerably.

What is known as the Middle Miocene mammalian fauna of

America shows some resemblance to that of the Lower Miocene of Europe, and question has been raised as to the time relations of the lower and middle divisions. In many respects there seems, however, closer correspondence of the American Middle Miocene, as represented by the Mascall and Pawnee Creek faunas, with the Middle Miocene of Europe than there is between these American faunas and that of any European Lower Miocene division. There is general agreement in the succeeding stages of the two areas, which indicates that the mammalian sequences of North America and Eurasia are brought into approximately the same relation throughout the later Tertiary series. If any difference exists, or if further adjustment occurs in the scale, it is doubtful whether this modification will do more than to bring to the same level the upper portion of the Lower Miocene of Europe and the lower portion of the Middle Miocene of America.

Significance of the Merychippus Zone of Coalinga with Relation to the Problem of Constructing the West American Tertiary Geological Scale

A summation of results obtained in a study of the position and relationships of the zone containing a *Merychippus* fauna in the North Coalinga region of California may be stated as follows:

1. The Merychippus zone is evidently included within the limits of the Monterey series of California as now defined.
2. The Merychippus zone evidently represents the faunal stage of the Turritella ocoyana zone, and the stratigraphic stage of the "Temblor" beds of F. M. Anderson.
3. The fauna of the Merychippus zone is not older than the stage of the Middle Miocene as represented by the Mascall and Virgin Valley faunas of the Great Basin region, and by the Pawnee Creek stage of the Great Plains area.
4. It seems inconceivable that the fauna of the Merychippus zone can represent any stage of the Oligocene of the mammal-bearing beds of western North America. The possibility that it represents any portion of the mammal-bearing Lower Miocene of this continent carries with it the supposition of wide divergence of faunas in different areas of America in Lower Miocene time.
5. The Mascall and Virgin Valley formations of the Great Basin region are of approximately the same age or older than the "Temblor."

6. The lack of adjustment between the time scale of the California area of the Pacific Coast Marginal Marine province and that of the Great Basin province suggests that correlation dependent on use of percentages of marine molluscan species as commonly defined has tended to place time divisions relatively too far from the present, in comparison with the original time scale of Europe. The lack of adjustment suggests further that the Middle Miocene mammal-bearing beds of North America should possibly occupy a lower position in the scale, in comparison with the scale of Europe, than that to which they have generally been assigned.

JACALITOS FAUNA

Within the limits of the beds mapped as Jacalitos a few vertebrate remains representing *Pliohippus?* were reported by Arnold and Anderson.[25] Additional material of this horse and specimens representing a *Neohipparion* species have been found by investigators since that time.

PLIOHIPPUS or PROTOHIPPUS

One specimen figured by Arnold and Anderson was determined by J. W. Gidley as *Pliohippus*. It represents a species of medium size with somewhat flattened protocone, and wide fossettes with slightly crinkled enamel walls. (See Figs. 28*a* and 28*b*.) Two teeth of a type similar to that from the Jacalitos figured by Arnold and Anderson were presented to the University by F. M. Anderson. They are two upper molars rather strongly curved, and with the protocone connected with protoconule. They were obtained in Sec. 35, T. 19 S., R. 15 E., M. D. B. and M. Section 35 is largely covered by the upper portion of the Jacalitos, with Etchegoin on the east side. The chances favor the occurrence of these teeth in the upper portion of the Jacalitos.

Fragments of horse teeth found by the University party in December, 1913, at three additional localities in the area mapped as Jacalitos represent advanced types of horses. All of these localities are at the base of the Jacalitos.

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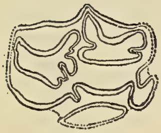
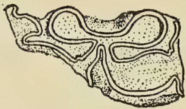
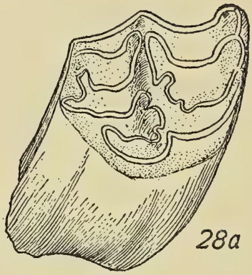
[25] Ralph Arnold and Robert Anderson, U. S. Geological Survey Bull. 398, p. 300, and pl. 33, figs. 3 and 3a, 1910.

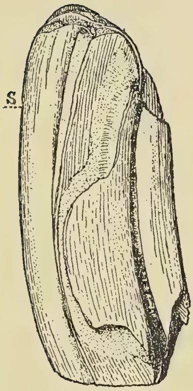
NEOHIPPARION

An interesting upper molar three (Figs. 26*a* and 26*b*, no. 21370, locality 2076) found by J. H. Ruckman at the base of the Jacalitos, but below the line as mapped by Arnold and Anderson, represents a species of *Neohipparion.* The much flattened protocone of this tooth is widely separated from the protoconule. The fossettes are rather narrow, and their walls are only moderately plicated.

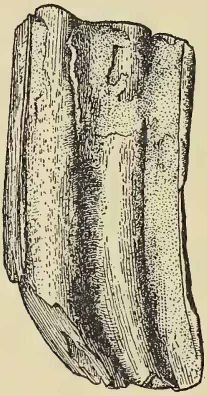

26*a*

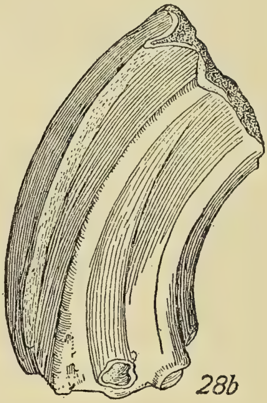

27*a*


28*a*



26*b*


27*b*


28*b*

Figs. 26*a* and 26*b*. *Neohipparion molle* Merriam. M$\underline{3}$?, no. 21370, natural size. Lower Jacalitos, North Coalinga region, California. Fig. 26*a*, section of tooth at point indicated by *s* on Fig. 26*b*; Fig. 26*b*, inner view.

Figs. 27*a* and 27*b*. *Neohipparion*, sp. M$\bar{2}$?, no. 21369, natural size. Lower Jacalitos, North Coalinga region, California. Fig. 27*a*, occlusal view; Fig. 27*b*, outer side.

Figs. 28*a* and 28*b*. *Pliohippus?*, sp. M$\underline{3}$, no. 165665, U. S. National Museum, natural size. Jacalitos formation, North Coalinga region, California. Adapted from Arnold and Anderson. Fig. 28*a*, occlusal view; Fig. 28*b*, posterior? view.

Compared with a number of practically perfect specimens of M$\underline{3}$ in the *Hipparion* collection from the Ricardo fauna of the Mohave area, this tooth is somewhat longer, the walls of the fossettes show less plication, the protocone is absolutely wider anteroposteriorly and much narrower transversely. The species represented by specimen 21370 is evidently distinct from the Ricardo forms, and from all other described *Hipparion* species of the Pacific Coast and Basin provinces. Whether it is a more or a less advanced species than the Mohave form is not entirely clear. The slightly greater length of crown, and the large, much-flattened protocone may indicate a more advanced stage in the Coalinga species. The *Neohipparion* species represented by no. 21370 is described as *Neohipparion molle.* This species is characterized by length and narrowness of upper molar crown, simplicity of enamel borders of the narrow fossettes, and unusually large anteroposterior diameter of the laterally compressed protocone.

A fragmentary long-crowned lower molar (no. 21369, Figs. 27*a* and 27*b*) from locality 2126 is very narrow transversely. The metaconid-metastylid column is very long anteroposteriorly, while the inner groove on this column is wide and deep. The antero-external region shows the sharp angle commonly seen in *Hipparion.* The fold separating the protoconid and hypoconid inserts its inner end between the folds separating protoconid and metaconid and hypoconid and metastylid. This tooth corresponds in many characters to DM$\bar{3}$ of *Equus occidentalis*, but is much too long to represent a temporary tooth. The characters of this tooth correspond in general to those of *Hipparion*, but it does not resemble the forms from the Ricardo fauna. In the Coalinga specimen the metaconid-metastylid column is wider anteroposteriorly, the groove between the metaconid and metastylid is wider, and the characters in general are suggestive of a more specialized form than those of Ricardo.

The Coalinga form seen in no. 21369 most nearly resembles a *Hipparion* or *Neohipparion* type quite certainly derived from the Rattlesnake Pliocene of the John Day region in eastern Oregon. Specimen 554 in the University collections from the John Day Valley was found in a basin containing both Rattlesnake Pliocene and Mascall Miocene, but the matrix covering the specimen is like the reddish-brown Rattlesnake beds, and very different from the white or gray Mascall beds of this area. The M$\bar{2}$ of this Rattlesnake specimen has dimensions near those of the Coalinga specimen. The metaconid-metastylid column shows a somewhat flatter outer groove in no. 21369, but this may be due to difference in wear. The Rattlesnake specimen shows a very prominent fold on the anterior side of the hypoconid. The corresponding region of the Coalinga specimen is broken away, but there is a sudden bend in the small portion of the wall remaining at this point suggesting the presence of this fold.

A *Hipparion* or *Neohipparion* form from the Thousand Creek beds of northern Nevada shows characters near those of the Rattlesnake form, and suggests the structure in no. 21369 from the Coalinga region, but these resemblances do not necessarily mean specific identity, and the Thousand Creek form may represent a distinct type.

It is perhaps significant that both the upper and the lower teeth referred to the genus *Hipparion* or *Neohipparion* suggest a type different from that of the well-known Ricardo species, and possibly more advanced. The Jacalitos species seems most nearly related to types of the Rattlesnake beds.

MEASUREMENTS

	No. 21370 Coalinga	No. 21311 Ricardo Unworn	No. 21369 Coalinga	No. 19847 Ricardo	No. 554 Rattlesnake	No. 19414 Thousand Creek
$M\underline{3}$, anteroposterior diameter	19.3 mm.[26]	21				
$M\underline{3}$, transverse diameter	15.8[1]	17.5				
$M\underline{3}$, length of crown	48	38				
$M\underline{3}$, anteroposterior diameter of protocone at middle height of crown	9.4	7.3				
$M\bar{2}$, greatest anteroposterior diameter			23.4	24.5	25.9	29
$M\bar{2}$, transverse diameter			11.4	9	10.5	11
$M\bar{2}$, length of crown			48 worn	48.9	57.5 worn	66
$M\bar{2}$, anteroposterior diameter of metaconid-metastylid column			15	11.1	14.4	14.6

AGE OF JACALITOS VERTEBRATE FAUNA

The Jacalitos fauna as now known is characterized by the presence of *Neohipparion* occurring only in the lowest beds, and by *Pliohippus* or *Protohippus* apparently occurring a little higher than the *Neohipparion* specimens in the basal portion of the section. Specimens resembling the *Pliohippus?* of this formation are presumed to come also from the upper portion of the section.

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[26] Approximate.

The time relations of the Jacalitos vertebrates to the faunas of the Great Basin province are not entirely clear, but the closest relationships seem to be with the Lower Pliocene.

FAUNAS OF THE ETCHEGOIN AREA

Vertebrate remains were found at numerous localities in the area mapped as Etchegoin. The forms obtained fall naturally into two groups. One fauna was found at a series of localities near the base of the section, the localities being in or above the zone of the pelecypod *Glycimeris coalingensis*. The other localities are scattered over an area underlain by the upper portion of the Etchegoin of this section.

PLIOHIPPUS COALINGENSIS ZONE

At several localities near the base of the Etchegoin section in this region, a fauna is found including remains of horses of a considerably more advanced type than those of the Jacalitos. The most characteristic form is *Pliohippus coalingensis*. This fauna is best known from localities 2073, 2074, 2078, and 2090. It comprises the following forms:

Pliohippus coalingensis (Merriam).
Pliohippus?, sp. small.
Procamelus?, sp.
Platygonus?, sp.

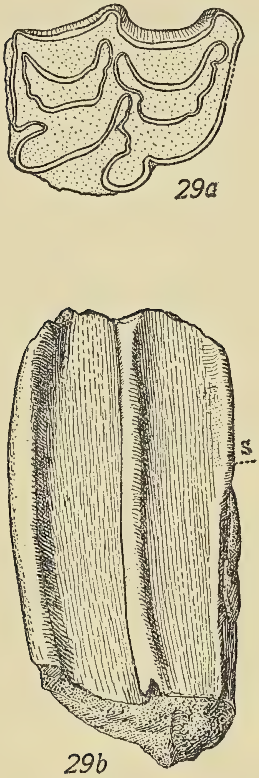
The faunal zone near the base of the Etchegoin in the North Coalinga region represents a distinctly more advanced stage than that of the Jacalitos.

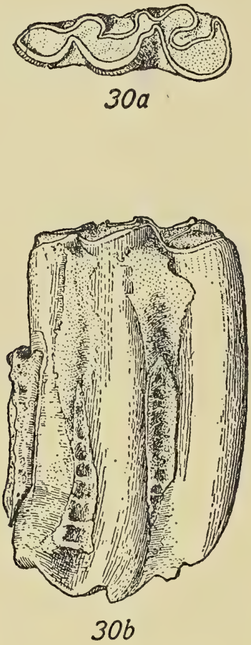
PLIOHIPPUS COALINGENSIS (Merriam, J. C.)

Protohippus coalingensis Merriam, J. C., *Science*, N. S., vol. 40, p. 645, August, 1914.

Type specimen no. 21341 from locality 2073. Lower Etchegoin ten miles north of Coalinga, California. A species of medium size, approaching the dimension of *Pliohippus supremus*. The type specimen (Figs. 29*a* and 29*b*) differs from the type specimen of *P. supremus* in the heavier mesostyle, relative narrowness of the crown even toward the base, narrower fossettes, much less complicated enamel walls of the fossettes, and much smaller more nearly circular protocone.

The nearest approach to this form among the Equidæ known west of the Wasatch is *Pliohippus fairbanksi*, a species imperfectly represented in the Ricardo beds of the Mohave Desert. The lower Etchegoin form resembles the Ricardo species approximately in size, in simplicity of the fossettes, in the very small, round protocone, and weak connection of the protoloph and metaloph. The crown of the Etchegoin form is, however, less curved and is much narrower. The narrowness of the Coalinga form is apparently a normal character of worn teeth. It may be that later collections will show that these two forms are specifically identical, or at most not removed farther than by subspecific characters.





FIGS. 29*a* AND 29*b*. *Pliohippus coalingensis* (Merriam). P$\underline{4}$, type specimen, no. 21341, natural size. Etchegoin formation, North Coalinga region, California. Fig. 29*a*, cross-section of tooth at point indicated by *S* on Fig. 29*b*; Fig. 29*b*, outer view.

FIGS. 30*a* AND 30*b*. *Pliohippus?*, sp. M$\overline{3}$, no. 21362, natural size. Etchegoin formation, North Coalinga region, California. Fig. 30*a*, occlusal view; Fig. 30*b*, outer view.

The imperfectly known *Pliohippus* species of the Thousand Creek beds seems to have a somewhat different form and differently constructed fossettes.

Pliohippus coalingensis is somewhat larger and more advanced than the *Pliohippus* or *Protohippus* species of the Jacalitos.

MEASUREMENTS

	No. 21341 Coalinga	No. 19789 Ricardo	P. supremus Type
P$\underline{4}$, transverse diameter	24.4 mm.	26	
P$\underline{4}$, anteroposterior diameter	27.2	25	
P$\underline{4}$, height of crown	53	55	
M$\underline{1}$, transverse diameter			25
M$\underline{1}$, anteroposterior diameter			24

PROTOHIPPUS or PLIOHIPPUS, sp.

Associated with *P. coalingensis* at locality 2074 are fragmentary remains of teeth evidently representing a species near the *Pliohippus?* of the Jacalitos. The material available is not sufficient to permit definite determination of the affinities of the form. At locality 2090 a lower molar, no. 21362 (Figs. 30*a* and 30*b*), represents a species that may be identical with the smaller protohippine form at locality 2074.

CAMELIDÆ

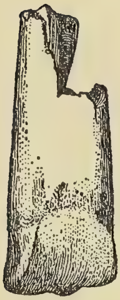
A single fragment of a metapodial (Fig. 31) from locality 2090 represents a camel approximating in size the large species of *Procamelus*.

SUIDÆ

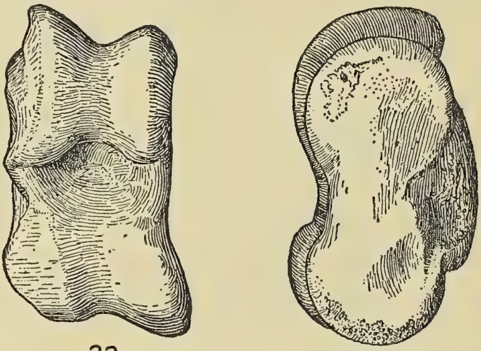
A single astragalus (no. 21371, Figs. 32*a* and 32*b*) from locality 2123 in the lower Etchegoin zone represents a peccary-like form. In dimensions and form it is near *Platygonus*. It is possible that this specimen belongs with the latest fauna from this region.

LATER FAUNA FOUND ON UPPER PORTION OF ETCHEGOIN AREA

Vertebrate remains were found in considerable quantity on exposures representing the upper portion of the Etchegoin section in the North Coalinga region. The members of the University party all obtained specimens in this area, but the largest part of the collection was secured by J. O. Nomland, who was engaged in making a special study of the Etchegoin and its relation to adjacent formations. The collections from this area were obtained from a considerable number of localities situated mainly in a zone ranging from one-half mile to a little more than a mile east of the Glycimeris zone at the base of the Etchegoin. The only exception to the rule is the possible representation of the fauna by a peccary astragalus at locality 2123 near the Glycimeris zone. The localities range in elevation from near 600 feet to a little more than 900 feet above sea level. At a number of localities this fauna is associated with invertebrates of several horizons representing the upper portion of this Etchegoin section. The vertebrate specimens were not found in place, but appeared on exposures which seemed to consist solely of Etchegoin material.



31



32a *32b*

Fig. 31. Camelid. Portion of distal end of metapodial. No. 21363, × ½. Etchegoin formation, North Coalinga region, California.

Figs. 32*a* and 32*b*. Astragalus of *Platygonus*-like form. No. 21371, natural size. Etchegoin? formation, North Coalinga region, California. Fig. 32*a*, superior view; Fig. 32*b*, medial view.

As the later fauna in general resembles that of the Pleistocene as closely as it does any known Pliocene of America, the writer made special inquiry as to the possibility of derivation of the specimens from Pleistocene accumulations. Terrace deposits bordering the Great Valley are reported in the region to the north of Coalinga at several levels, some of which are considerably above that at which the collections representing the later fauna were made. The bones were all obtained on hills seemingly consisting entirely of Etchegoin, and with no suggestion of terrace deposits. However, it is known that important terraces in the region to the north may have an exceeding small amount of material left upon them, so that the rarity of loose material may not indicate absence of terraces. Members of the University party who collected vertebrate remains in this area state that there are terraces at levels both above and below the localities at which bones were collected, and that the hills upon which the vertebrate material was obtained seem to have been formed by erosion since the upper terraces were completed, while the lower terraces do not reach up to the level of these hills.

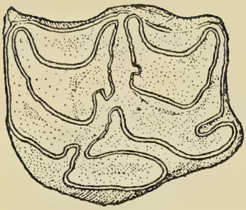
It does not appear to the writer that final evidence as to the occurrence of this fauna is now before us. Since the question is of importance it is desirable to continue the examination of this area with a view to obtaining material in place.

The fauna found in the upper Etchegoin area includes the following forms:

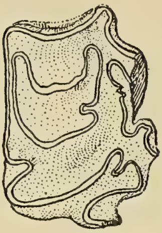
Equus or *Pliohippus*, sp.
Camelops or *Pliauchenia*, sp.
Procamelus?, sp.
Cervus or *Odocoileus*, sp.
Tayassu or *Mylohyus?*, sp.
Mastodon.
Testudo?, sp.
Fish vertebræ, and scattered bulbous fish bones.

EQUUS or PLIOHIPPUS, sp.

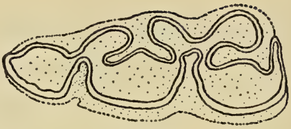
The equid remains known from the upper Etchegoin area include upper and lower molars, the astragalus, and all of the phalanges. The molars are very large, exceeding slightly the dimensions of the largest specimens of *Pliohippus* available for comparison. The form of the upper cheek-teeth (Figs. 33*a* to 34*b*) strongly resembles that of *Equus*. The protocone differs from that of all *Pliohippus* species known to the writer in its relatively great anteroposterior diameter. Suggestions of *Pliohippus* are seen in the simplicity and unusual width of the fossettes, in the somewhat more slender mesostyle, and in the convex inner face of the protocone. The protocone is also short anterior to its union with the protoconule. The general form of the protocone may, however, be approximated in *Equus*.



33a



34a



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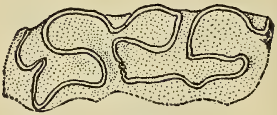

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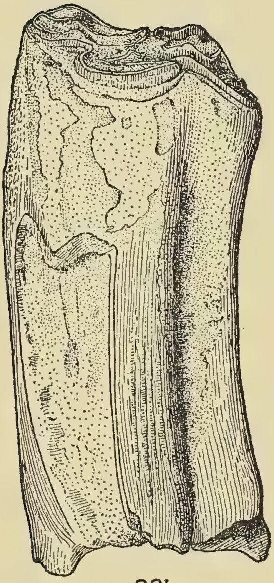

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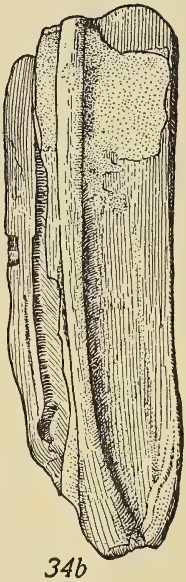

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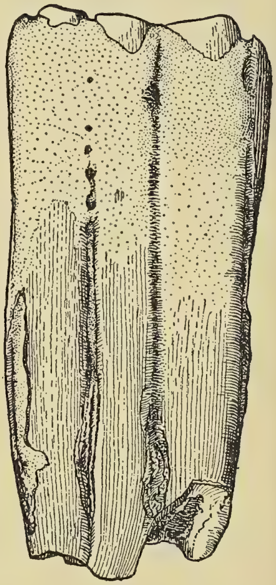


36b

FIGS. 33*a* AND 33*b*. *Equus* or *Pliohippus*, sp. $M\underline{1}$, no. 21330, natural size. From upper Etchegoin area, North Coalinga region, California. Fig. 33*a*, occlusal view, outer enamel wall absent; Fig. 33*b*, inner view.

FIGS. 34*a* AND 34*b*. *Equus* or *Pliohippus*, sp. $P\underline{4}$?, no. 21331, natural size. From upper Etchegoin area, North Coalinga region, California. Fig. 34*a*, occlusal view; Fig. 34*b*, outer view.

FIG. 35. *Equus* or *Pliohippus*, sp. $M\bar{3}$, occlusal view. No. 21333, natural size. From upper Etchegoin area, North Coalinga region, California.

FIGS. 36*a* AND 36*b*. *Equus* or *Pliohippus*, sp. $M\bar{1}$?, no. 21332, natural size. From upper Etchegoin area, North Coalinga region, California. Fig. 36*a*, occlusal view; Fig. 36*b*, inner view.

MEASUREMENTS

	mm.
P$\underline{4}$?, transverse diameter (no. 21331)	29
M$\underline{1}$, anteroposterior diameter (no. 21330)	30
M$\underline{1}$, anteroposterior diameter of protocone (no. 21330)	8.8

The lower cheek-teeth (Figs. 35 to 36*b*) are large, long, and heavily cemented. The dimensions approximate those of the largest specimens of *Equus occidentalis* from the Pleistocene of California. The crowns are larger and relatively narrower than in any *Pliohippus* available to the writer for comparison. The metaconid-metastylid column is divided internally by a deep, wide groove, which approaches more nearly the normal form in *Equus* than to that in typical *Pliohippus*.

MEASUREMENTS

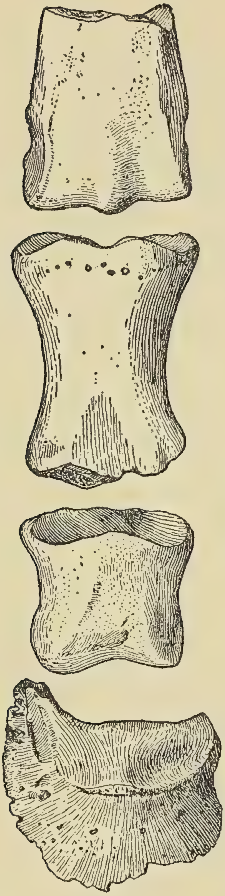
	mm.
No. 21332	
Lower cheek-tooth, anteroposterior diameter	34.1
No. 21333	
M$\bar{1}$, anteroposterior diameter	27.5
M$\bar{3}$, anteroposterior diameter	36.2
M$\bar{3}$, transverse diameter	13.8

The limb elements (Fig. 37), including the astragalus, metapodials, and the phalanges, are somewhat smaller than in average specimens of *Equus caballus*, or in the Pleistocene *Equus occidentalis*. The form of the limb elements is much as in *E. caballus*. If it differs appreciably from modern species, the difference is in the more slender form of the Coalinga specimens. The proximal end of a metacarpal shows the facets as in *Equus*. The distal keels of several metapodials are large and prominent. In one specimen representing an ungual phalanx the lateral wing of the hoof is somewhat smaller than in *Equus caballus*.

A summation of the characters of the equid form from the upper Etchegoin area shows that it very closely approaches the *Equus* group. If, as is suggested by certain characters of the upper molars, there is close affinity with *Pliohippus*, this would seem the most advanced species thus far known in that group, and one presumably furnishing a transition to *Equus*.

PROBOSCIDEAN REMAINS

A considerable number of fragments representing a mastodon-like form have been found at several localities in the upper Etche-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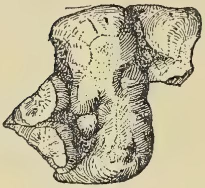
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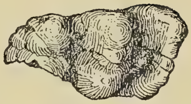
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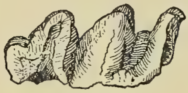
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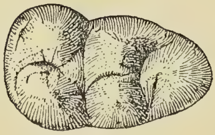
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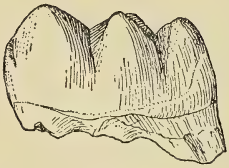
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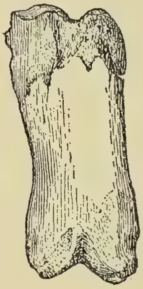
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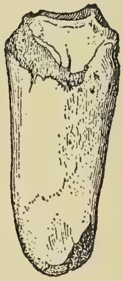
41b

Fig. 37. *Equus* or *Pliohippus*, sp. Anterior view of distal end of third metapodial, and phalanges of third digit. No. 21380 (not all elements known to represent one individual), × ½. From upper Etchegoin area, North Coalinga region, California.

Fig. 38. Portion of a mastodon cheek-tooth seen from above. No. 21339, × ¼. From upper Etchegoin area, North Coalinga region, California.

Figs. 39*a* and 39*b*. Portion of a mastodon cheek-tooth. No. 21340, × ½. From the upper Etchegoin area, North Coalinga region, California. Fig. 39*a*, occlusal view; Fig. 39*b*, lateral view.

Figs. 40*a* and 40*b*. $\text{M}\bar{3}$ of *Mylohyus*-like form. No. 21360, natural size. From upper Etchegoin area, North Coalinga region, California. Fig. 40*a*, occlusal view; Fig. 40*b*, side view.

Figs. 41*a* and 41*b*. Proximal phalanx of *Platygonus* or *Mylohyus*-like form. No. 21338, natural size. From upper Etchegoin area, North Coalinga region, California. Fig. 41*a*, superior view; Fig. 41*b*, side view.

goin area. The greater part of a tooth (no. 21339, Fig. 38) was found at locality 2119, and another tooth of different form (no. 21340, Figs. 39*a* and 39*b*) at locality 2079. The first specimen represents a very large mastodon, which is, so far as determinable, not far from the stage of development of the Pleistocene species. The second specimen apparently represents a smaller form with narrower teeth. Neither form is necessarily excluded from the types of mastodon occurring in the Pliocene.

SUIDÆ

Two large third lower molars represent a peccary-like type not previously known in the Pacific Coast region. The tubercles are low, blunt-conical as in *Tayassu* and *Mylohyus*, and are not distinctly connected by transverse crests as in *Platygonus*. Intermediate tubercles do not appear as well developed as in the *Tayassu* and *Mylohyus* specimens examined by the writer. In size the larger specimen (Figs. 40*a* and 40*b*) corresponds approximately to *Mylohyus*, sp. *a* from Conard Fissure, as figured by Brown.[27]

This form is near *Tayassu* or *Mylohyus*. If other specimens show somewhat advanced development of the secondary tubercles, it may represent *Mylohyus*. The species is probably new.

MEASUREMENTS

	No. 21360 mm.	No. 21359 mm.
$M\bar{3}$, greatest anteroposterior diameter	27.2	24.3
$M\bar{3}$, transverse diameter	15.9	13.4

A single proximal phalanx (no. 21338, Figs. 41*a* and 41*b*) from locality 2079 represents a form near *Platygonus*, but the element is a little less enlarged inferiorly than that genus. This difference is possibly due in part to wear on the fossil specimen.

CAMELIDÆ

Remains representing two groups of camels are found in the upper Etchegoin area. One contains forms near *Camelops* or *Pliauchenia*. The other type is not more than half as large as the first, and is possibly a representative of a large species of *Procamelus*. The two species were found at locality 2119.

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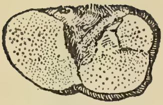
[27] Brown, B., *Mem. Amer. Mus. Nat. Hist.*, vol. 9, pl. 24, 1908.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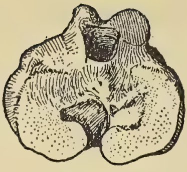
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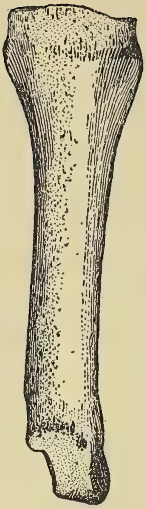
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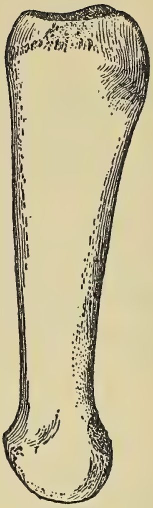
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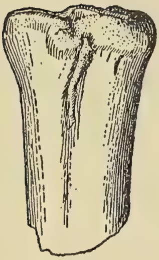
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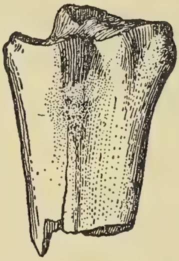
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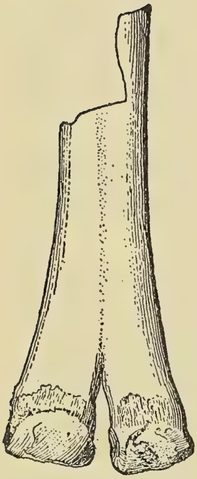
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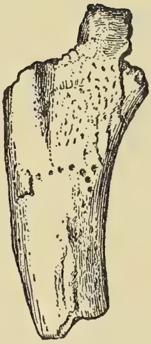
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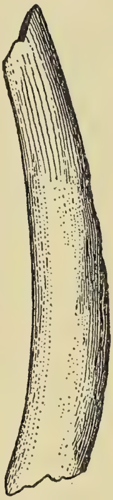
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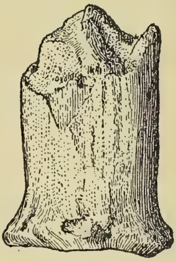
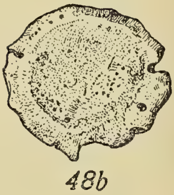

48a


48b

FIGS. 42*a*–43. Metapodials of large *Camelops*-like form. From upper Etchegoin area, North Coalinga region, California. Figs. 42*a* and 42*b*, proximal end of anterior cannon-bone. No. 21334, × ¼. Fig. 42*a*, proximal view; Fig. 42*b*, anterior view. Fig. 43, anterior view of distal end of metapodial, possibly of posterior limb. No. 21379, × ¼.

FIGS. 44*a* AND 44*b*. *Procamelus?*, sp. Proximal end of cannon-bone from posterior limb. No. 21335, × ½. From upper Etchegoin area, North Coalinga region, California. Fig. 44*a*, proximal view; Fig. 44*b*, anterior view.

FIGS. 45*a* and 45*b*. *Pliauchenia?*. Proximal phalanx. No. 21356, × ½. From upper Etchegoin area, North Coalinga region, California. Fig. 45*a*, superior view; Fig. 45*b*, side view.

FIGS. 46–48*b*. *Cervus* or *Odocoileus*, sp. From upper Etchegoin area, North Coalinga region, California. Fig. 46, portion of flattened forked antler. No. 21336, × ½. Fig. 47, portion of slender tine with round cross-section. No. 21337, × ½. Figs. 48*a* and 48*b*, base of antler with burr. No. 21357, × ½. Fig. 48*a*, lateral view; Fig. 48*b*, basal view.

The first form is represented by large metapodial fragments (nos. 21334 and 21379, Figs. 42*a* to 43). A proximal phalanx and several fragmentary bones possibly belong also to this type. This animal was near the size of *Camelops hesternus* of the California Pleistocene. The metapodial fragments (no. 21334 and 21379) of the large camel represent the proximal end of an anterior cannon-bone, and the distal portion of an element which is possibly from the hind limb. The proximal end of the anterior cannon-bone is closely similar to that of *Camelops*. The main difference between this specimen and that of *Camelops hesternus* from Rancho La Brea suggested is in the slightly fuller bridge of bone uniting metacarpals three and four posteriorly at the proximal end. If the fragment of the distal end of a cannon-bone represents an anterior limb, this element is more slender than in *Camelops hesternus*.

A proximal phalanx (Figs. 45*a* and 45*b*, no. 21356) from locality 2370 is longer and much more slender than the phalanges of the *Camelops* species from Rancho La Brea, or than in the large camel of the Pleistocene Manix beds in the Mohave area. It evidently represents a large species quite different from the Pleistocene *Camelops* forms, and from all other camels known in the Pacific Coast Pleistocene. It possibly corresponds to *Pliauchenia* or to some genus other than *Camelops*.

The second camelid form known from the upper Etchegoin area is represented by the proximal end of a posterior cannon-bone (no. 21335) of an adult individual somewhat larger than the Recent llama. This animal was less than half the bulk of *Camelops hesternus* or of the *Camelops*-like form represented by specimen no. 21334. The form of the proximal end of the cannon-bone (Figs. 44*a* and 44*b*) is entirely different from that of *Camelops* and *Camelus*. It is much narrower transversely, and the posterior facet for the cuboid is much larger than in *Camelops*. The form is near that of *Procamelus*, though the transverse diameter is a little larger than in any *Procamelus* species available for comparison. The facets for the cuboid and mesocuneiform are lunate instead of oval as in *Procamelus*.

CERVIDÆ

At several localities (no. 2119, 2079, 2370 and 2374) in the upper Etchegoin area fragments of antlers have been found representing forms of a cervid type. Two specimens consist of the basal portion with the burr of large antlers that had been shed. They evidently represent a very advanced form of the true cervid type. The larger specimen (Figs. 48*a* and 48*b*, no. 21357) is from an individual with antlers approximating in size those of large specimens of the Recent *Cervus* or *Odocoileus*.

One specimen (no. 21336, Fig. 46) consists of a flattened beam apparently dividing above into two branches of different dimensions. The shape of the beam is like that in *Cervus*, and resembles a form that may occur in *Merycodus*. It is larger than in specimens of the nearest forms of *Merycodus* known to the writer, and the branches above are more uneven in size than in *M. necatus*, the nearest merycodont. Another specimen (no. 21337, Fig. 47) is a portion of a long, slender, gently curved tine or branch with nearly circular cross-section. The convex side of the tine shows a double row of very small, irregular tubercles separated by a faint groove. This tine is larger than that of any merycodont examined by the writer.

The evidence before us indicates that the specimens from this fauna represent a true cervid of the *Odocoileus* or *Cervus* type.

TESTUDINATE REMAINS

A fragment of a carapace representing a very large tortoise-like form (no. 21378, Figs. 49*a* and 49*b*) was obtained with the collection found in the upper Etchegoin area. The species is unlike any form known in this region at the present time.

AGE OF LATER FAUNA FROM UPPER ETCHEGOIN AREA

The aspect of the later fauna from the Etchegoin area resembles in some features that of the Pleistocene. The horse in this assemblage seems more advanced than any American Pliocene form known to the writer. *Equus simplicidens* Cope from the Blanco Pliocene of Texas is considered by Gidley[28] to represent *Pliohippus*. The protocone of the Coalinga species is very large, long anteroposteriorly, compressed laterally, and nearly flat on the inner side. In Cope's figure of *E. simplicidens* the protocone is incomplete, but seems smaller than in the Coalinga form, and is restored as smaller by Gidley.

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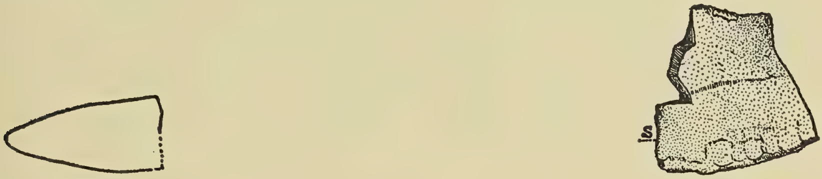
[28] Gidley, J. W., *Bull. Amer. Mus. Nat. Hist.*, vol. 14, p. 124, 1901.

The metapodial of the larger camel in this fauna approaches that of a Pleistocene *Camelops*, but the large phalanges, apparently representing this fauna, do not correspond to any of the Pleistocene camel species known in the Pacific Coast region. The smaller camel seems more nearly to represent a Pliocene *Procamelus* or some allied group. The cervid remains represent deer of a distinctly modern type. Nothing of this character has been known in the Pliocene of America so far as the writer is aware. The peccary is of an advanced type and is near the Pleistocene stage of development. The mastodon remains are fragmentary, and little weight has been placed on them in distinction between Pliocene and Pleistocene. This is true also of the tortoise, and of the fish remains.



49a 49b

Figs. 49*a* and 49*b*. Portion of carapace of a large tortoise. No. 21378, × ½. From the upper Etchegoin area, North Coalinga region, California. Fig. 49*b*, superior view of marginal? plate, lateral margin to left of figure; Fig. 49*a*, transverse section at *s*, at lower end of Fig. 49*b*.

In attempting to fix the age of the fauna it is first necessary to determine whether the collection available comes from one source or whether it is derived from two or more sets or deposits. It is possible that one part comes from Pleistocene terraces, and that other elements, such as the *Procamelus*, are from the Etchegoin formation. The fact that both the small camel, and the large species show difference from the known Pleistocene forms naturally suggests that a really new faunal assemblage is present here. However, it will be difficult to give satisfactory evidence that this is a faunal unit until some of the forms with a distinctly Pleistocene aspect have been found in place in the Etchegoin, or until some of those representing an older type, as the *Procamelus*-like form, have been discovered in terrace deposits.

If the fauna is a unit and occurs in place in the Etchegoin, it indicates either that the Etchegoin is younger than the Miocene or Pliocene stage which it has been presumed to represent, or that a modern type of fauna has appeared relatively early in California.

The Etchegoin, upon the outcrops of which the odd Cervus fauna is found, is a formation of considerable thickness. It is covered by the Tulare, which is generally considered to be represented by much more than 2,000 feet of strata. Since the close of Tulare time important events referred to the Pleistocene have taken place in this region. From purely physical studies there seems good reason for believing that the upper portion of the Etchegoin represents an epoch separated from Recent time by a considerable period.

The invertebrate fauna of the upper portion of the Etchegoin area from which the vertebrate remains were obtained consists, according to Mr. Nomland, of about forty-nine species of which twenty are extinct. Arnold and Anderson[29] considered the Etchegoin as of Miocene age. The total fauna was noted to contain 65 per cent. of extinct species. Arnold and Anderson were in agreement with F. M. Anderson that the Etchegoin is to be correlated with the San Pablo formation. Arnold and Anderson also considered the upper Etchegoin as the equivalent of the lower Purisima. The most recent studies of Bruce Clark, Bruce Martin, and J. O. Nomland, show that the Etchegoin fauna is distinctly more recent than that of the San Pablo. The suggestion that the Etchegoin was contemporaneous with the San Pablo, but of a different geographic phase, seems not to be adequate in view of the fact that the San Pablo fauna closely matches that of the "Santa Margarita" occurring in the second formation below the Etchegoin, and separated from it by the stage referred to the Jacalitos in the North Coalinga region.

From the lower portion of the Tulare formation above the Etchegoin, Arnold and Anderson[30] list thirteen species, of which all but three are considered as extinct forms. It was suggested by these authors that the basal portion of the Tulare represented the lower Pliocene, but that the upper portion extended into the Pleistocene.

It appears to the writer improbable that the Etchegoin can be included in the Miocene. The assemblage of evidence from a study of the invertebrate faunas, interpreted in terms of the Lyellian percentage method as it was understood when that method was proposed, suggests Pliocene age. This was the determination given by F. M. Anderson in the original description of the Etchegoin.

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[29] Arnold, R., and Anderson, R., U. S. Geol. Surv. Bull. 398, p. 139, 1910.

[30] Arnold, R., and Anderson, R., U. S. Geol. Surv. Bull. 398, p. 154, 1910.

If the vertebrates obtained from the upper portion of the Etchegoin area in the North Coalinga region were actually derived from Etchegoin strata, we apparently have a relatively advanced fauna in beds which according to evidence from geology and invertebrate palæontology suggest Pliocene age. This relation of the evidence from vertebrate and invertebrate palæontology is in a manner similar to that in the lower portion of the Coalinga geologic section, where the "Temblor" invertebrates are determined as older than the vertebrate Merychippus fauna. The fact that the relation is the same in the Etchegoin area as in the "Temblor" area may suggest that the vertebrate fauna actually occurs in the Etchegoin strata. If this is true, the balance of evidence would seem to the writer to indicate that the strata in question are not older than middle Pliocene.

Alternative possibilities of explanation that remain open are the suggestion that this peculiar fauna is derived from vestiges of terraces that reached only across the outer or upper portion of the Etchegoin area, or that it is composed in part of Pleistocene terrace material and in part of Pliocene forms derived from strata of the Etchegoin formation. Although the field work already done has been carefully conducted, the final settlement of this important problem seems to require still more intensive study.

TABLE REPRESENTING POSITION OF FORMATIONS CONTAINING VERTEBRATE FAUNAS IN NORTH COALINGA REGION

The following table gives approximate position of beds containing land vertebrate faunas in the North Coalinga region in comparison with the situation of the principal divisions of the geological scale in the Great Basin and California regions.

Geological Periods		Local Formations, California Area	Local Formations, Great Basin Province	Faunal Zones	
				Vertebrate Faunas	Invertebrate Faunas
Pleistocene		Rancho La Brea	Manix	Smilodon Equus Camelops Elephas Stages not defined	Echinarachnius excentricus Turritella jewetti
Pliocene		Tulare		Hyænognathus	
		Etchegoin			Echinarachnius gibbsii
		Jacalitos	Thousand Creek Rattlesnake Ricardo	Ilingoceras Pliohippus Hipparion	
Miocene	Upper	San Pablo ("Santa Margarita")	Barstow Beds	Merychippus calamarius Merycodus necatus	Astrodapsis
	Middle	Monterey ("Temblor")	Mascall and Virgin Valley	Merychippus isonesus Parahippus Dromomeryx	Turritella ocoyana
	Lower	? "Vaqueros"	Columbia Lava	No known fauna	Turritella inezana
Oligocene	Upper		Upper John Day	Promerycochoerus	
	Middle	San Lorenzo	Middle John Day	Eporeodon	Turritella diversilineata
	Lower		? Lower John Day	Imperfectly known fauna	
Eocene	Upper	Tejon	Upper Clarno	No fauna (Flora—Sequoia heeri, Betula, Alnus, Quercus, Acer, Ficus)	Turritella merriami Turritella uvasana
	Lower	Martinez	Lower Clarno	No fauna (Flora—Lygodium, Asplenium, Equisetum, Juglans, Magnolia)	Turritella pachecoensis Turritella infragranulata

LIST OF IMPORTANT LOCALITIES AT WHICH VERTEBRATE SPECIMENS WERE COLLECTED IN THE NORTH COALINGA REGION

All Townships and Ranges Referred to Mount Diablo Base and Meridian

MERYCHIPPUS ZONE—
- Locality 2124: SW. ¼ sec. 28, T. 18 S., R. 15 E.

JACALITOS—
- Locality 2126: NE. ¼ of NE. ¼ of sec. 15, T. 19 S., R. 15 E.
- Locality 2076: SW. ¼ of sec. 34, T. 18 S., R. 15 E.
- Locality 2077: NE. ¼ sec. 15, T. 19 S., R. 15 E.

ETCHEGOIN, PLIOHIPPUS COALINGENSIS ZONE—
- Locality 2073: SW. ¼ sec. 13, T. 19 S., R. 15 E.
- Locality 2074: SW. ¼ sec. 12, T. 19 S., R. 15 E.
- Locality 2078: NW. ¼ of SW. ¼ sec. 13, T. 19 S., R. 15 E.
- Locality 2090: NW. ¼ sec. 13, T. 19 S., R. 15 E.

FAUNA FROM UPPER ETCHEGOIN AREA—
- Locality 2079: the NW. ¼ of NW. ¼ sec. 19, T. 19 S., R. 16 E.
- Locality 2080: NW. ¼ of SW. ¼ sec. 6, T. 19 S., R. 16 E.
- Locality 2082: SW. ¼ of NE. ¼ sec. 1, T. 19 S., R. 15 E.
- Locality 2084: north line of SE. ¼ of sec. 12, T. 19 S., R. 15 E.
- Locality 2086: N.W. ¼ of SW. ¼ of sec. 6, T. 19 S., R. 16 E.
- Locality 2089: NW. ¼ of sec. 19, T. 19 S., R. 16 E.
- Locality 2119: SE. ¼ of sec. 12, T. 19 S., R. 15 E.
- Locality 2368: NW. ¼ of the SW. ¼ of sec. 19, T. 19 S., R. 15 E.
- Locality 2370: NE. ¼ of sec. 25, T. 19 S., R. 15 E.
- Locality 2372: NE. ¼ of the SE. ¼ of sec. 25, T. 19 S., R. 15 E.
- Locality 2374: W. ½ of the NW. ¼ of sec. 25, T. 19 S., R. 15 E.

NEW HORSES FROM THE MIOCENE AND PLIOCENE OF CALIFORNIA

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INTRODUCTION

In a study of the Tertiary mammalian faunas of California several new species of protohippine horses have appeared. The designation of these forms is desirable at this time in order that reference to the species may be possible in publications which will appear in advance of the papers including detailed descriptions of the new forms.

MERYCHIPPUS SUMANI, n. sp.

Merychippus, near *calamarius*. Merriam, J. C., Univ. Calif. Publ. Bull. Dept. Geol., vol. 6, p. 168, pl. 29, figs. 1*a* to 1*c*, 1911.

Type specimen, no. 21422. Barstow Upper Miocene, Mohave Desert, California.

Upper cheek-teeth much smaller than in typical *Merychippus calamarius* or in *M. intermontanus*. Crowns of cheek-teeth considerably elongated, markedly curved, and well cemented; height of the crowns often equal approximately to twice their width. Protocone round, tending toward circular form in cross-section, and discrete up to a stage of very advanced wear. Enamel bordering the fossettes commonly more complicated than in any of the larger *Merychippus* forms of the Barstow Miocene.

This species includes the smallest members of the *Merychippus* series in the Barstow Miocene. It is closely related to *Merychippus calamarius*, and may possibly represent merely a variety of that

University of California Publications, Bulletin of the Department of Geology, vol. 9, no. 4, pp. 49–58, November 22, 1915.

group. In the characters of the cheek-teeth this species approaches *Hipparion*, from which it is distinguished by the more strongly curved crowns of the upper teeth, and by the greater simplicity of the enamel borders of the cement lakes. The cement covering of the cheek-teeth is commonly thinner than in *Hipparion*, and there is no evidence of functional cement on the milk molars.

Named in honor of John R. Suman who furnished the first specimen of this species used in study of the Mohave Tertiary faunas.

MEASUREMENTS OF TYPE SPECIMEN, No. 21422

Length, anterior side M^1 to posterior side M^3	57. mm
P^4, anteroposterior diameter	22.
P^4, transverse diameter	20.8
P^4, height of crown	31.3
M^1, anteroposterior diameter	19.
M^1, transverse diameter	19.4
M^1, height of crown	28.5
M^2, anteroposterior diameter	20.8
M^2, transverse diameter	18.1
M^2, height of crown	32.8
M^3, anteroposterior diameter	19.7
M^3, transverse diameter	15.5
M^3, height of crown	32.6

MERYCHIPPUS INTERMONTANUS, n. sp.

Type specimen, no. 21400. An upper cheek-tooth dentition from locality 1401 in the Barstow Miocene of the Mohave Desert, California.

Cheek-teeth large; crowns long, strongly curved, heavily cemented. Protocone of upper cheek-teeth uniting early with protoconule. Enamel walls bordering the fossettes comparatively simple.

This form includes the largest members of the *Merychippus* type in the Barstow Upper Miocene of the Mohave Desert. It is distinguished from the typical *Merychippus calamarius* by its larger size, longer crowns, heavier cementation, and more pronounced tendency to union of the protocone and protoconule even in young individuals. The species more closely approaches the *Protohippus* type than does typical *M. calamarius*, and might by some authors be included within the limits of that genus. It is here referred to *Merychippus* rather than to *Protohippus*, as the milk dentition of a number of specimens presumably representing this type seems to show less cement on the crowns of the cheek-teeth than in typical *Protohippus*.

Measurements of Type Specimen, No. 21400

Length, anterior side P^2 to posterior side M^3	146. mm.
Length, anterior side P^2 to posterior side P^4	78.8
Length, anterior side M^1 to posterior side M^3	67.
P^2, anteroposterior diameter	29.8
P^2, transverse diameter	18.5
P^3, anteroposterior diameter	24.5
P^3, transverse diameter	22.7
P^3, height of somewhat worn crown	44.
P^4, anteroposterior diameter	24.9
P^4, transverse diameter	21.
M^1, anteroposterior diameter	24.
M^2, anteroposterior diameter	24.
M^2, transverse diameter	21.7
M^2, height of crown	43.
M^3, anteroposterior diameter	*a*22.
M^3, transverse diameter	*a*18.

a, approximate.

PROTOHIPPUS TEHONENSIS, n. sp.

Type specimen an upper molar, no. 21779, from the Tejon Hills, southern end of San Joaquin Valley, California.

Upper molar crown strongly curved and well cemented; outer styles of moderate strength; protocone considerably flattened transversely and connected with the protoconule by a wide isthmus; fossettes wide transversely and showing plication of enamel only on the adjacent borders.

The West-American forms nearest *P. tehonensis* are a rare *Protohippus* or *Pliohippus* represented by no. 21423 from the Barstow Upper Miocene, and a form referred to *Pliohippus* occurring in the lower portion of the Jacalitos Pliocene of the North Coalinga region. The Barstow species is near *P. tehonensis* in form and dimensions, but differs slightly in form of the protocone, strength of the enamel, and possibly in degree of cementation of the crowns. It seems to the writer doubtful whether the Barstow and Tejon Hills forms are specifically identical. The North Coalinga species described by Arnold and Anderson[1] from the Jacalitos formation, and determined as *Pliohippus*, approaches *P. tehonensis* very closely and may be specifically identical. As yet we have only three teeth from the Jacalitos and all represent M^3, so that a fully satisfactory comparison cannot be made.

Pliohippus tantalus of the Ricardo Pliocene is larger and heavier

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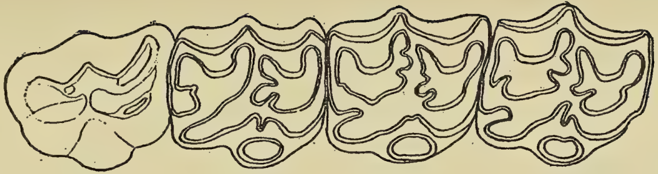
[1] Arnold, R., and Anderson, R., Bull. U. S. Geol. Survey, no. 398, p. 98, 1910.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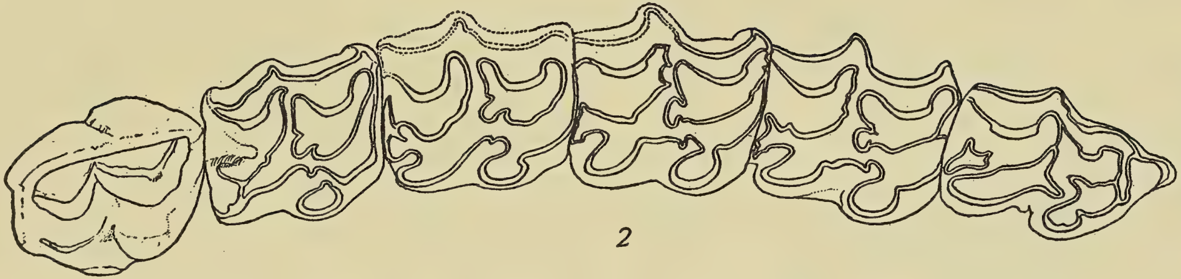
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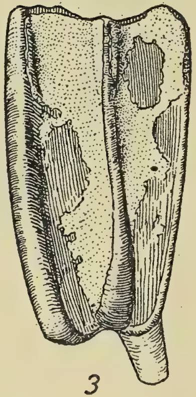
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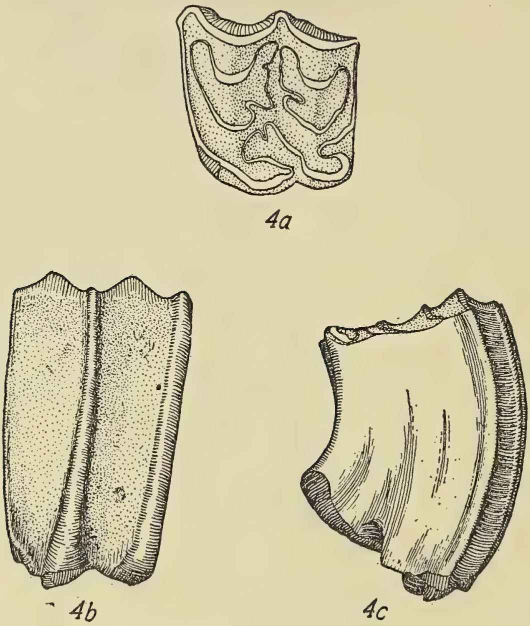
Fig. 1. *Merychippus sumani*, n. sp. Type specimen, no. 21422, superior cheek-teeth, occlusal view, natural size. From the Barstow Upper Miocene, Mohave Desert, California.

Figs. 2 and 3. *Merychippus intermontanus*, n. sp. Type specimen, no. 21400, natural size. From the Barstow Upper Miocene, Mohave Desert, California. Fig. 2, superior cheek-tooth series, occlusal view; fig. 3, M^2, outer view.

than the Tejon Hills species, its fossettes are larger and differently formed. A *Pliohippus* species from Ricardo near *P. mirabilis* resembles the Tejon Hills species in dimensions, but seems to differ in details of form of fossettes and is presumably not of the same species.



Figs. 4*a* to 4*c*. *Protohippus tehonensis*, n. sp. M^1?, type specimen, no. 21779, from the Tejon Hills, southern end of the San Joaquin Valley, California. Fig. 4*a*, occlusal view; fig. 4*b*, outer view; fig. 4*c*, posterior view.

MEASUREMENTS OF TYPE SPECIMEN, No. 21779

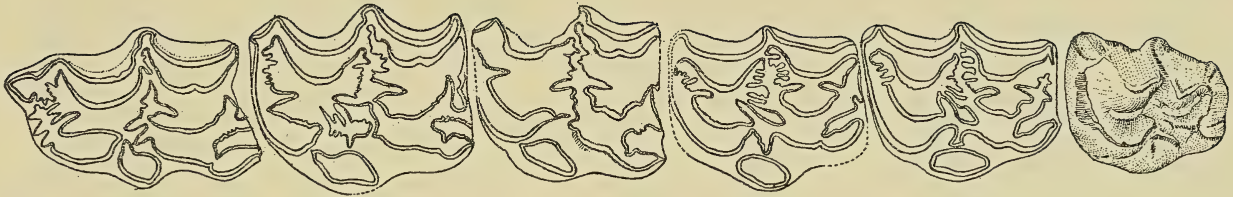
?M^1, anteroposterior diameter	22.5 mm.
?M^1, transverse diameter	23.7
?M^1, anteroposterior diameter of protocone	*a*8.4

a, approximate.

HIPPARION MOHAVENSE CALLODONTE, n. var.

Type specimen, no. 21311, a finely preserved dentition including the upper and lower cheek-teeth with several of the incisors. Collected in the Ricardo Pliocene near Ricardo Postoffice, on the western border of the Mohave Desert, by Emerson M. Butterworth.

In this form the dentition differs noticeably from that of the typical *Hipparion mohavense* of the Ricardo Pliocene. The proto-



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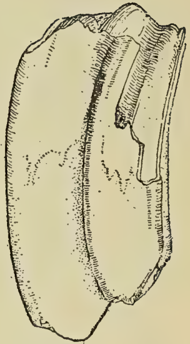

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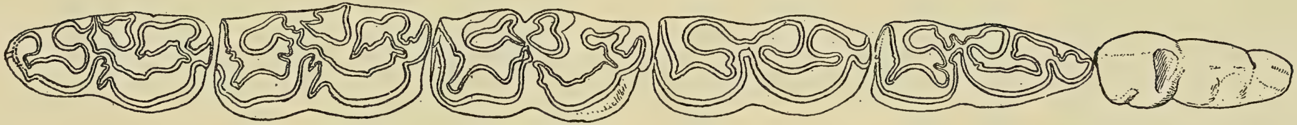


7

Figs. 5 to 7. *Hipparion mohavense callodonte*, n. var. Cheek-tooth series, no. 21311, natural size. From the Ricardo Pliocene, near Ricardo Post-office, Mohave Desert, California. Fig. 5, superior cheek-tooth, occlusal view; fig. 6, M^3, outer view; fig. 7, inferior cheek-teeth, occlusal view.

cone is more strongly flattened transversely, while the enamel pattern of the teeth in general shows fewer deep, smoothly-rounded folds. The plications of the enamel in this form tend to be more distinctly angular, and there are more numerous minute folds. The dimensions differ somewhat from those of the typical *H. mohavense.* The differences in dimensions and in pattern of the cheek-teeth separating this variety from typical *H. mohavense* may be due in some part to variation in stage of wear, but the characters seem sufficiently marked to require at least tentative recognition in the classification. It is possible that fuller collections may ultimately show an intergradation between this form and *H. mohavense.*

Measurements of No. 21311

P^2, anteroposterior diameter	29.9 mm.	P_2, anteroposterior diameter	28.4 mm.
P^2, transverse diameter	20.2	P_2, greatest transverse diameter	12.
P^3, anteroposterior diameter	27.4	P_3, anteroposterior diameter	27.
P^3, transverse diameter	23.2	P_3, greatest transverse diameter	13.7
P^4, anteroposterior diameter	24.8	P_4, anteroposterior diameter	27.4
P^4, transverse diameter	21.5	P_4, greatest transverse diameter	13.
P^4, height of mesostyle	45.5	P_4, height of protoconid	51.
M^1, anteroposterior diameter	24.5	M_1, anteroposterior diameter	25.8
M^1, transverse diameter	22.6	M_1, greatest transverse diameter.	11.4
M^2, anteroposterior diameter	24.	M_2, anteroposterior diameter	27.3
M^2, transverse diameter	20.4	M_2, greatest transverse diameter.	10.8
M^2, height of mesostyle	41.	M_2, height of protoconid	44.4
M^3, anteroposterior diameter	21.	M_3, anteroposterior diameter	25.
M^3, transverse diameter	18.	M_3, greatest transverse diameter.	10.4

Pliohippus fairbanksi, n. sp.

Type specimen, a large unworn upper cheek-tooth P^4?, no. 19789, from the Ricardo Pliocene, near Ricardo Postoffice, California.

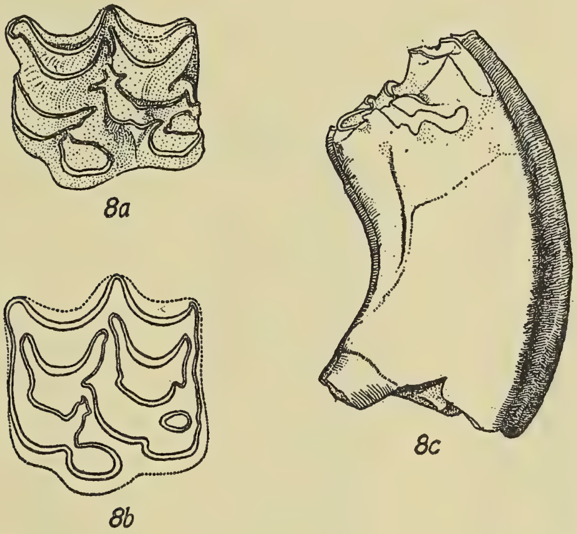
The type specimen of *P. fairbanksi* represents a protohippine form differing considerably from *Pliohippus tantalus* of the Ricardo Pliocene. The crown is a little more strongly curved and the styles are heavier. The fossettes are narrower and have a distinctly different form. The protocone is small and round. In this particular specimen the protoloph and metaloph remain separate almost to the base of the tooth.

The nearest approach to the form seen in specimen no. 19789 is that in a tooth type (no. 21341) from the Etchegoin Pliocene of the North Coalinga region of California, on the western border of the San Joaquin Valley. The Etchegoin form shows rather narrow fossettes, a very small, round protocone, and a weak connection of protoloph and metaloph. The cheek-teeth of the Etchegoin species are considerably narrower and less curved than the Ricardo form, and appear to be specifically different.

This species is named in honor of Dr. H. W. Fairbanks, who was one of the earliest investigators to study the Ricardo Pliocene beds.

MEASUREMENTS OF TYPE SPECIMEN, No. 19789

P^4, height of crown on outer side	55	mm.
P^4, anteroposterior diameter	25	
P^4, transverse diameter	26.4	


8a

8b

8c

FIGS. 8*a* TO 8*c*. *Pliohippus fairbanksi*, n. sp. P^4?, type specimen, no. 19789, natural size. From the Ricardo Pliocene near Ricardo Postoffice, Mohave Desert, California. Fig. 8*a*, occlusal view; fig. 8*b*, section at base of upper third of crown; fig. 8*c*, posterior view.

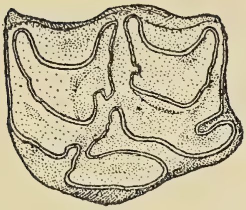
EQUUS OR PLIOHIPPUS, probably new

Equus or *Pliohippus*, sp. Merriam. Amer. Phil. Soc. Trans., n.s., vol. 22, pt. 3, p. 223, 1915.

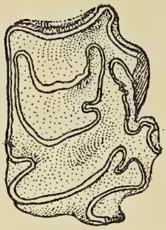
Upper and lower cheek-teeth, from beds in the upper portion of the Etchegoin formation north of Coalinga.

Cheek-teeth large, long-crowned, heavily cemented. Upper cheek-teeth with heavy mesostyle, fossettes wide with moderately crinkled enamel borders. Protocone large, strongly compressed laterally, inner border convex. Metaconid-metastylid column of lower cheek-teeth often with wide inner groove.

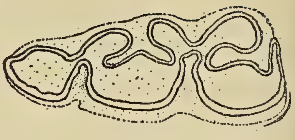
Of the described species this form most closely approaches *Equus* or *Pliohippus simplicidens* of the Blanco Pliocene. It possibly



9a



10a



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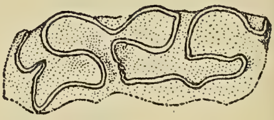
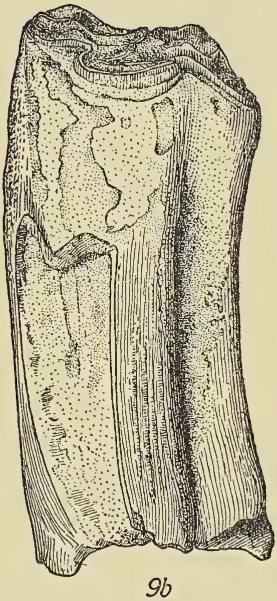
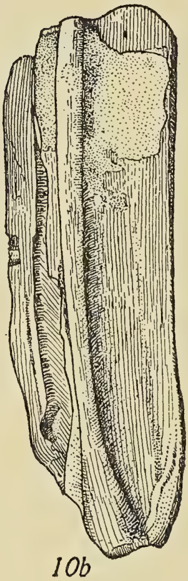


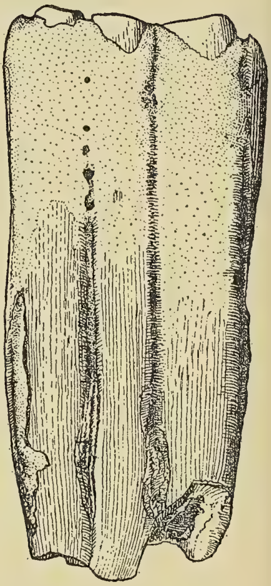
12a



9b



10b



12b

FIGS. 9*a* AND 9*b*. *Equus* or *Pliohippus*, sp. M^1, no. 21330, natural size. From upper Etchegoin beds, North Coalinga region, California. Fig. 9*a*, occlusal view; fig. 9*b*, inner view.

FIGS. 10*a* AND 10*b*. *Equus* or *Pliohippus*, sp. P^4?, no. 21331, natural size. From upper Etchegoin beds, North Coalinga region, California. Fig. 10*a*, occlusal view; fig. 10*b*, outer view.

FIG. 11. *Equus* or *Pliohippus*, sp. M_3, occlusal view. No. 21333, natural size. From upper Etchegoin beds, North Coalinga region, California.

FIGS. 12*a* AND 12*b*. *Equus* or *Pliohippus*, sp. P_4?, no. 21332, natural size. From upper Etchegoin beds, North Coalinga region, California. Fig. 12*a*, occlusal view; fig. 12*b*, inner view.

differs from *Equus simplicidens* in somewhat greater width of the fossettes of the upper cheek-teeth and in the greater anteroposterior diameter of the protocone. The form of the protocone is not fully shown on Cope's figure of the type specimen of *E. simplicidens*, but this pillar is restored by Cope and Gidley as relatively shorter than in the Coalinga species. According to Gidley the teeth of *E. simplicidens* have the appearance of being comparatively short-crowned. The lower teeth referred to *E. simplicidens* are characterized by the angular nature of the groove on the inner side of the metaconid-metastylid column. In a specimen, no. 21333, from North Coalinga this groove is rather sharply angular. In specimen no. 21332 the groove is wider and approaches the form seen in *Equus*.

The occurrence of this species in the upper portion of the Etchegoin formation shows the existence of a relatively advanced type of horse in the California region, at a time near middle Pliocene.

As nearly as can be determined from the fragmentary material available this species is intermediate between advanced Pliohippus-like forms and *Equus*. The internal wall of the protocone is convex, instead of concave, as normally the case in *Equus*, but the anterior end of the protocone is scarcely extended anteriorly beyond the isthmus uniting protocone with protoconule. If the characters of this form are satisfactorily represented in the specimens at hand, and only one form is represented, the species would seem to furnish a transition between *Equus* and *Pliohippus*.

No name is given to this form at present as more and better material is desired before final estimation of the characters is made.

Transmitted October 23, 1915

RELATIONSHIP OF EQUUS TO PLIOHIPPUS SUGGESTED BY CHARACTERS OF A NEW SPECIES FROM THE PLIOCENE OF CALIFORNIA

CONTENTS

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Pliohippus proversus, n. sp. 1353
Relationships 1357
Measurements 1360

INTRODUCTION

Recent studies of late Cenozoic Equidae[1] from the Pacific Coast province of the United States have shown the existence of a California Pliocene horse exhibiting advanced characters in some respects intermediate between those of typical *Equus* and typical *Pliohippus*. As considerable uncertainty has existed concerning the immediate ancestry of *Equus*, any evidence furnished by the new California form is of special significance, and should therefore be presented in detail for use in studies on the evolution of this group. It seems particularly desirable to make available significant new materials received since the last published reference to this peculiar form.

The studies on West Coast Equidae leading to the statement in the following article have been greatly facilitated by cordial co-operation of Professor Henry F. Osborn and Doctor William D. Matthew of the American Museum of Natural History. Through courtesies extended in the use of collections and of organized studies made by the Museum, it has been possible to reach interpretations of new Pacific Coast collections which would otherwise have been attained with difficulty. Material assistance in study of the *Pliohippus* group was also given by Professor Richard S. Lull of Yale University through preparation of excellent casts representing the dentition

University of California Publications, *Bulletin of the Department of Geology*, vol. 9, no. 18, pp. 525–534, March 20, 1916.

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[1] Merriam, J. C., Trans. Amer. Phil. Soc., n. s., vol. 22, part 3, p. 33, 1915; also Univ. Calif. Publ. Bull. Dept. Geol., vol. 9, p. 56, 1915.

and feet of the type specimen of *Pliohippus pernix*. It is with pleasure that the writer acknowledges the co-operation of those who have contributed to the furtherance of this and of other related investigations. It is presumably not an exaggeration to state that, at this stage in the advance of science, there can be little hope of material progress in new work without such co-operation as tends to make the individual investigator merely one among many assisting in the advance movement in a given direction.

PLIOHIPPUS PROVERSUS, n. sp.

Equus or *Pliohippus*, sp. Merriam, J. C., Trans. Amer. Phil. Soc., n. s., vol. 22, part 3, p. 33, 1915.

Equus or *Pliohippus*, probably new. Merriam, J. C., Univ. Calif. Publ. Bull. Dept. Geol., vol. 9, p. 56, 1915.

Type specimen an upper cheek-tooth, M[1] or M[2], no. 21330, from the upper portion of the Etchegoin formation, locality 2079, North Coalinga region, western border of the San Joaquin Valley, California.

Cheek-teeth large, long-crowned, heavily cemented. Upper cheek-teeth slightly curved; mesostyle heavy; fossettes wide to narrow, with moderately crinkled enamel borders; protocone large, strongly compressed laterally in the molars, inner border convex or nearly flat. Lower cheek-teeth with short or long parastylid; metaconid-metastylid column commonly long anteroposteriorly and narrow transversely, inner groove wide, flat as in *Equus*, or somewhat narrowed tending toward the angular form seen in *Pliohippus;* outer faces of protoconid and hypoconid either convex or somewhat flattened.

Limb elements, so far as known, much like those of *Equus*. Unciform facet of metacarpal III sloping away from the plane of the magnum at approximately the angle shown in *Equus*. Lateral digits apparently much reduced distally and feet presumably monodactyle.

As indicated in earlier publications,[2] the advanced equid of the upper Etchegoin finds its nearest American relatives in *Equus* (*Pliohippus*) *simplicidens*[3] and *Equus* (*Pliohippus*) *cumminsii* of the Blanco Pliocene in Texas. Like the California species the two Texas forms are known by very imperfect material in which the lower dentition furnishes the better representation. The Blanco species were considered by Cope[4] to represent ancient types of the *Equus* group with relatively simple characters. It is interesting to note in this connection that the peculiar characters of Cope's *Equus simplicidens* furnished some of the most important evidence used in determining the age of the Blanco beds.

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[2] Merriam, J. C., *op. cit.*, 1915.

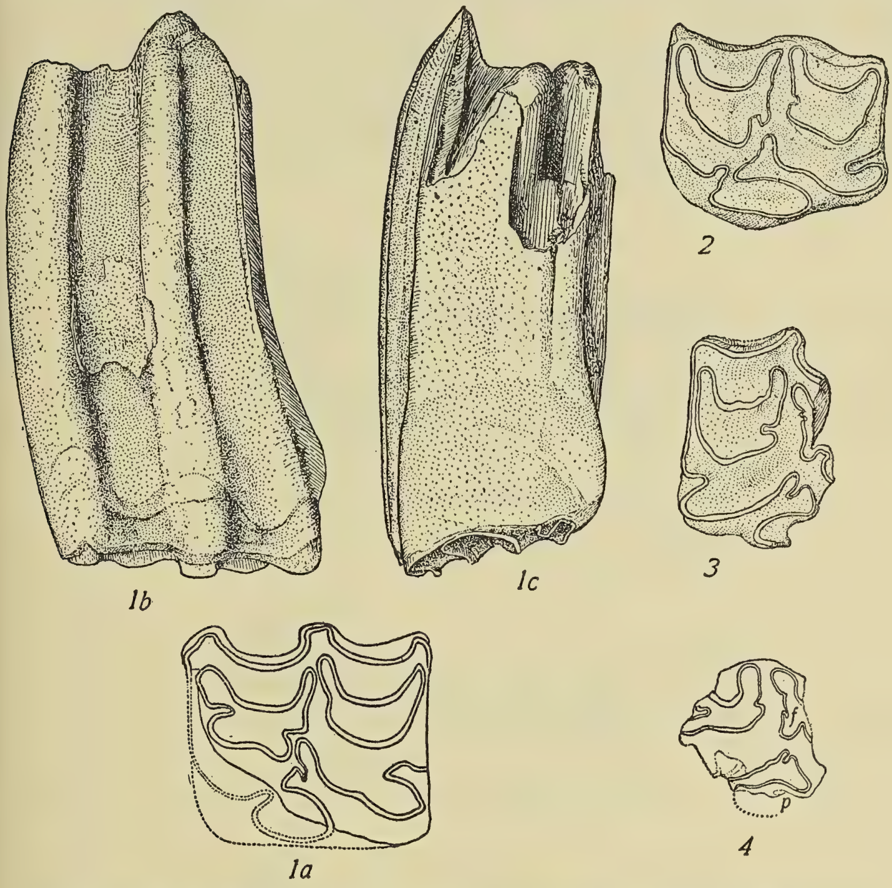
[3] Referred to *Equus* by E. D. Cope (Geol. Surv. Texas, 4th Ann. Rep. for 1893, p. 66); but considered as *Pliohippus* by J. W. Gidley (Bull. Amer. Mus. Nat. Hist., vol. 14, p. 123, 1901).

[4] Cope, E. D., Proc. Amer. Phil. Soc., vol. 30, p. 125, 1892.

The upper cheek-teeth of *P. proversus* (figs. 1*a* to 4), as well as of the *P. simplicidens* and *P. cumminsii* types, are distinguished from those of *Pliohippus* as represented in the typical form, *P. pernix*, by straighter crowns, with heavier mesostyle; tendency to narrowing of the fossettes; and especially by the form of the protocone. In typical *Pliohippus* the protocone is nearly circular in cross-section in the pre-molars, but tends to flatten toward the posterior end of the molar series. In the *P. proversus* type the protocone is relatively wide transversely in the premolar region, but is flatter or narrower transversely in all of the cheek-teeth than in *P. pernix*.

The upper cheek-teeth in *P. proversus* and in the other members of this group are distinguished from those of *Equus* especially by the form of protocone (see figs. 13 to 16). In typical *Equus* this pillar is normally longer anteroposteriorly, flatter transversely, reaches farther forward in advance of the isthmus connecting it with the protoconule, and is concave rather than convex on the inner side. There is also in *Equus* a stronger tendency to flattening of the outer faces of the paracone and metacone, the mesostyle inclines to be thicker, and the fossettes are usually narrower and have more strongly folded walls. In *E. stenonis* of the Old World and in *E. occidentalis* of California, the distinctive characters separating *Equus* from the *P. proversus* group are largely reduced in value. The form of protocone in *E. stenonis* may approach that of typical *Pliohippus* in nearly all characters, as it often tends to do in the milk dentition of modern *Equus*. In *E. occidentalis* the protocone is commonly short anteroposteriorly and may be nearly as Pliohippus-like as in the known *P. proversus* specimens. Both in *E. stenonis* and *E. occidentalis* the combination of all characters present in any given tooth is, however, commonly such as to indicate closer relation to modern *Equus* forms than to the *P. proversus* group.

The lower cheek-teeth of the upper Etchegoin *P. proversus* resemble those of a series described by Cope from the Blanco Pliocene of Texas, and referred to *P. simplicidens*. The Blanco teeth (fig. 17) are characterized by their considerable size, heavy cementation, and by the anteroposterior length of the metaconid-metastylid column. The metaconid-metastylid column commonly shows a rather sharply angular internal groove. Cope[5] considered the character of this column distinctive of *P. simplicidens*, in contrast with the *Equus* forms of the Pleistocene. In *P. simplicidens* the outer walls of the protoconid and hypoconid are convex to flattened.



Figs. 1*a* to 4. *Pliohippus proversus*, n. sp. From the upper Etchegoin Pliocene of the North Coalinga region, California. Figures approximately natural size.

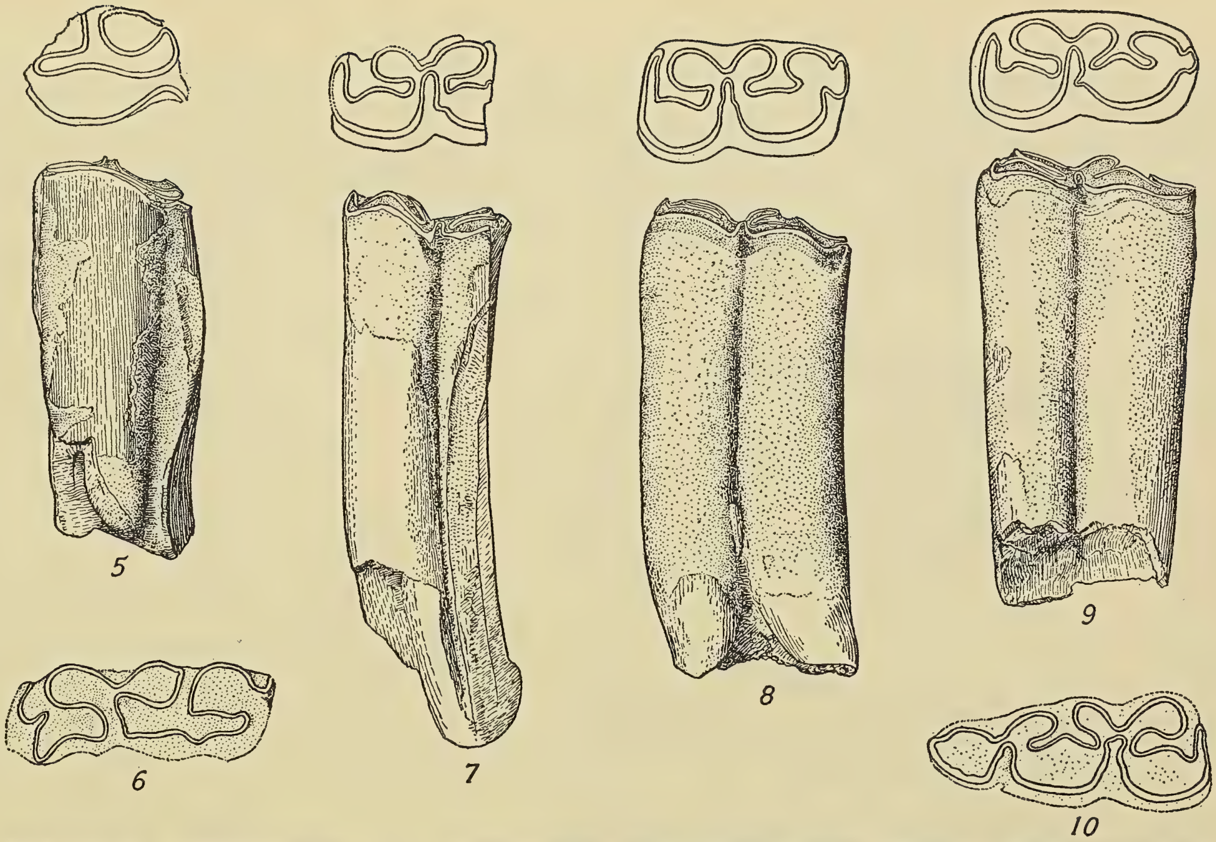
Figs. 1*a*, 1*b*, and 1*c*. P^3?, no. 22328; fig. 1*a*, occlusal view; fig. 1*b*, outer view; fig. 1*c*, posterior view.

Fig. 2. M^1 or M^2, no. 21330, type specimen, occlusal view.

Fig. 3. P^4?, no. 21331, occlusal view.

Fig. 4. Portion of an upper cheek-tooth, no. 22329, occlusal view; *p*, protocone; *f*, prefossette.

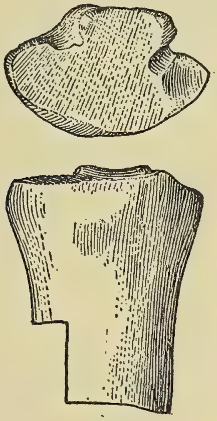
[5] Cope, E. D., Geol. Surv. Texas, 4th Ann. Rep. for 1893, p. 66.



Figs. 5 to 10. *Pliohippus proversus*, n. sp. Upper Etchegoin Pliocene, North Coalinga, California. Figures natural size.

Fig. 5. Inferior cheek-tooth, no. 22316, outer and occlusal views.
Fig. 6. P_4?, no. 21332, occlusal view.
Fig. 7. Inferior molar, no. 22330, outer and occlusal views.
Fig. 8. M_1?, no. 22312, outer and occlusal views.
Fig. 9. M_2, no. 22314, outer and occlusal views.
Fig. 10. M_3, no. 21333, occlusal view.

In the lower teeth of the *P. proversus* type from the upper Etchegoin the crowns are large, long, and heavily cemented. The metaconid-metastylid column in a number of specimens (figs. 5, 6, and 7) is wide anteroposteriorly and the internal groove is broad and flat. The width and flatness of the groove sometimes considerably exceed that in the simpler variations of *Equus*. In other lower cheek-teeth from the upper Etchegoin (figs. 8, 9, and 10) the inner groove of the metaconid-metastylid column is sharper than in *Equus* and more nearly resembles that in typical *Pliohippus*.



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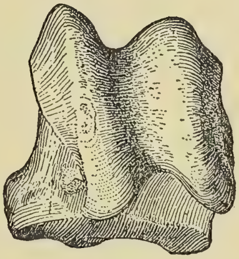

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Figs. 11 and 12. *Pliohippus proversus*, n. sp. From the upper Etchegoin Pliocene of the North Coalinga region, California. Both figures one-half natural size.

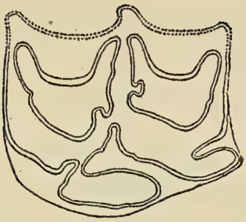
Fig. 11. Left metacarpal III, no. 22318, anterior and proximal views.

Fig. 12. Astragalus, no. 22334.

The form of the lower cheek-teeth in *P. proversus* is close to that of the Blanco material referred by Cope to *P. simplicidens*. The two types may be specifically different, but they apparently represent a group, which, as is shown in the upper cheek-teeth, appears separable from *Equus*, and does not correspond closely to typical *Pliohippus*.

Relationships

The horses referred to the *Pliohippus proversus* type from the upper Etchegoin Pliocene of California are distinct from all of the most advanced horses of the lower Etchegoin and Ricardo Pliocene stages of the Pacific Coast province. There is, however, in certain



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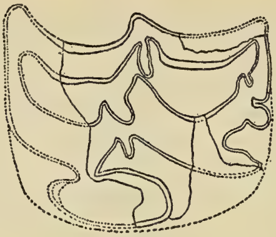

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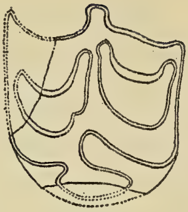

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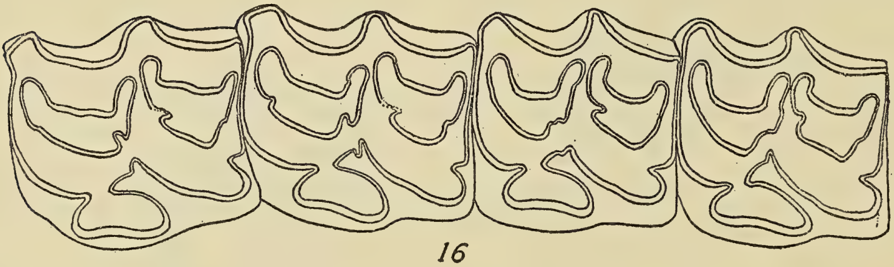

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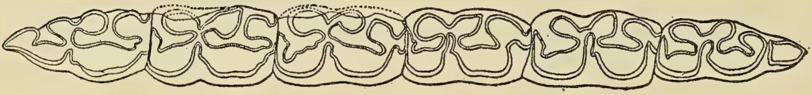

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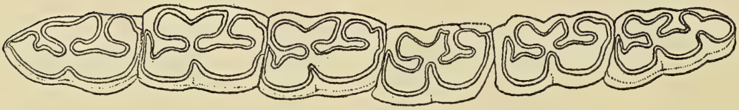

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FIG. 13. *Pliohippus proversus*, n. sp. M^1 or M^2, type specimen, no. 21330, natural size. Upper Etchegoin, North Coalinga region, California.

FIG. 14. *Pliohippus simplicidens* (Cope). Superior premolar?, natural size, Blanco Pliocene, Texas. (After Cope.) The inner single dotted line in reconstruction of the protocone represents the writer's interpretation of this pillar.

FIG. 15. *Pliohippus cumminsii* (Cope). Superior molar, natural size. Blanco Pliocene, Texas. (After Cope.)

FIG. 16. *Equus occidentalis* Leidy. P^3 to M^2, no. 21001, natural size. Pleistocene, Rancho La Brea, California.

FIG. 17. *Pliohippus* referred to *simplicidens* (Cope). Lower cheek-tooth series, one-half natural size. Blanco Pliocene, Texas. (After Cope.)

FIG. 18. *Equus occidentalis* Leidy. Lower cheek-tooth series, no. 12269, one-half natural size. Pleistocene, Rancho La Brea, California.

characters sufficiently close resemblance to some of the Ricardo species to suggest that the upper Etchegoin form may be derived by modification from one of the early Pliocene Pacific Coast species near *Pliohippus tantalus* or *P. fairbanksi*.

In considering the relation of *P. proversus* to forms of American faunas later than the upper Etchegoin, it is interesting to note that *Equus occidentalis* of the California Pleistocene represents the North American species of *Equus* in which the characters of the cheek-teeth show greatest simplicity. The gap between *P. proversus* and *E. occidentalis* is too wide to permit the conclusion that the later of the two is derived immediately from the earlier (see figs. 1*a* to 10, 13, 16, and 18). In this connection it should be noted that the upper Etchegoin stage, in which *P. proversus* occurs, is separated from the Pleistocene horizon containing *E. occidentalis* by the Tulare formation, representing a thickness estimated by Arnold and Anderson[6] to include at least three thousand feet of strata.

Of the Old World forms later than the upper Etchegoin stage of the Pliocene, the type most nearly approaching *P. proversus* is *Equus stenonis*,[7] described from the Pliocene and Pleistocene, and representing the least progressive Old World type of the genus *Equus*. In some respects *E. stenonis* approaches the *P. proversus* type more closely than does the American *E. occidentalis*. This may be due to the origin of *E. stenonis* either in America or in Eurasia at a time earlier than the Pleistocene stage of *E. occidentalis*. The Tulare formation of California represents such a time in the geologic sequence. The fauna of the Tulare is as yet very imperfectly known, and no horse remains have been reported from these beds. It is probable that a stage less advanced than *E. occidentalis* and more progressive than *P. proversus* will yet be obtained from the Tulare section.

The similarity in general characters of *Pliohippus proversus* of the upper Etchegoin to the two *Pliohippus* species of the Blanco Pliocene, considered with similarity of the vertebrate faunas of the Blanco and upper Etchegoin leaves little room for doubt that *P. proversus*, *P. simplicidens*, and *P. cumminsii* represent closely allied forms of nearly the same epoch. In the characters of both upper and lower cheek-teeth the forms of this group are intermediate between typical *Pliohippus* and typical *Equus*, and represent the nearest approach to the *Equus* type found among American Tertiary horses. The geologic occurrence of these species represents a stage following the time of maximum development of *Pliohippus* and apparently preceding the earliest known occurrence of true *Equus*. The evidence presented in this sequence of horse types in America indicates that some, at least, of the *Equus* forms of this continent were derived from *Pliohippus* along a line of evolution passing through or near the *P. proversus* group.[8] Whether, as has been held by several writers, certain Old World forms included in *Equus* had an independent origin by way of *Hipparion* may still be a field for discussion. *Equus sivalensis* and *E. namadicus* reported from the uppermost Siwalik beds of India,[9] are held to represent true *Equus*, and have been considered as possible derivatives from *Hipparion*. Much remains to be known concerning the characters of these forms, as also concerning their exact occurrence in the geologic scale. Should the uppermost Siwalik fauna containing species referred to *Equus* prove to be late Pliocene there would seem to be abundant opportunity for origin of the Indian forms from an American type of the geologic stage represented by *P. proversus*, as the upper Etchegoin beds lie below the great Tulare section, which has been presumed to be mainly, if not entirely, Pliocene.

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[6] Arnold, Ralph & Anderson, Robert, U. S. Geol. Surv. Bull. 398, p. 147, 1910.

[7] See Major, Forsyth, C. J., Abhl. Schw. Palae. Ges., vol. 4, Taf. 1 and 2, 1877; also *ibid.*, vol. 7, Taf. 7, 1880.

MEASUREMENTS

	P. simplicidens	P. cumminsii	P. proversus No. 22328	E. occidentalis No. 21001
P^3, anteroposterior diameter	....	....	33 mm.	30.4
P^3, transverse diameter	....	....	28.5	28.2
P^3, anteroposterior diameter of protocone	....	....	*a*10.7	11.9
			No. 21331	
P^4, anteroposterior diameter	*a*31 mm.	....	....	30.2
P^4, transverse diameter	*a*27	....	29	28.4
P^4, anteroposterior diameter of protocone	*a*12	....	*a*10.2	12
			No. [10]21330	
M^1, anteroposterior diameter	....	22	30	26.3
M^1, transverse diameter	....	*a*25.5	*a*27	27.1
M^1, anteroposterior diameter of protocone	....	9.5	13.8	11.1
M^2, anteroposterior diameter	....	....	....	27.5
M^2, transverse diameter	....	....	....	26.8
M^2, anteroposterior diameter of protocone	....	....	....	12.8

a, approximate.

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[8] The line of evolution from *Pliohippus* to *Equus* has been recognized by many writers, although the stages of transition have not been fully indicated.

[9] See Lydekker, Richard, Palaeontologia Indica, ser. 10, vol. 2, part 3, pp. 21 to 30, pls. 14 and 15, 1882; also Pilgrim, Guy E., Records Geol. Surv. India, vol. 43, part 4, p. 324, 1913.

[10] M^1 or M^2.

	P. simplicidens	P. cumminsii	P. proversus No. 21332	E. occidentalis No. 12269
P_2, anteroposterior diameter	39 mm.	....	....	34
P_2, transverse diameter	16.5	....	....	17.8
P_2, anteroposterior diameter of metaconid-metastylid column	16.5	....	....	15.9
P_3, anteroposterior diameter	33.6	....	....	29.8
P_3, transverse diameter	17	....	....	17
P_3, anteroposterior diameter of metaconid-metastylid column	20	....	....	18.3
P_4, anteroposterior diameter	33	....	34.1	29.5
P_4, transverse diameter	17	....	....	18.2
P_4, anteroposterior diameter of metaconid-metastylid column	20	....	17.7	17.7
			No. 21333	
M_1, anteroposterior diameter	32	....	27.5	26
M_1, transverse diameter	15.5	....	....	17
M_1, anteroposterior diameter of metaconid-metastylid column	16.5	....	....	13.9
			No. 22314	
M_2, anteroposterior diameter	31	....	27	27
M_2, transverse diameter	15.8	....	12.8	17.3
M_2, anteroposterior diameter of metaconid-metastylid column	17	....	13.6	14.8
			No. 21333	
M_3, anteroposterior diameter	37	....	36.2	31.5
M_3, transverse diameter	14.1	....	13.8	16
M_3, anteroposterior diameter of metaconid-metastylid column	16.5	....	14.7	13.4

a, approximate.

Transmitted March 14, 1916

TERTIARY VERTEBRATE FAUNA FROM THE CEDAR MOUNTAIN REGION OF WESTERN NEVADA

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INTRODUCTION

In a study of the Tertiary faunas of the Great Basin province, now being carried on by the Department of Palaeontology of the University of California, one of the most fruitful investigations has been that comprising the exploration of the Cedar Mountain region of western Nevada. This area was visited by Charles L. Baker and John P. Buwalda in the summer of 1912 in the hope of finding a Tertiary mammalian fauna in deposits situated between the occurrences of Tertiary beds at Virgin Valley and Thousand Creek on the northern border of Nevada, and those of the Barstow and Ricardo areas of the Mohave Desert to the south.

Information regarding the occurrence of fossil remains in the area visited by Baker and Buwalda had previously been received through the courtesy of Mr. T. Holman Buck of Mina, Nevada, and through Professor George J. Young of the University of Nevada. Mr. Buck very kindly visited the localities with Baker and Buwalda, and was instrumental in securing and transporting to the railroad some of the most interesting material, notably the type specimen of a new and interesting anchitheriine horse. The area was visited by Dr. Buwalda in July, 1914, for the purpose of reviewing the work carried on in 1912.

The expedition in 1912 secured a significant collection, including a considerable variety of mammalian forms. Although the amount of material obtained is relatively small, the faunal representation is almost as large as that of the Barstow fauna, and in importance the area ranks with the Virgin Valley and Mohave localities.

In the preparation of the following report on the fauna of the Cedar Mountain region the writer has been especially indebted to Charles L. Baker and John P. Buwalda for their energetic prosecution of the field work through which the collection was obtained, and to Mr. Buck of Mina, Nevada, for information leading to location of the material and for subsequent assistance in packing and transporting the collection.

The drawings used in illustration of the Cedar Mountain fauna were all prepared by Mrs. Louise Nash.

OCCURRENCE

As represented on plate 8, the Cedar Mountain region lies a little more than fifty miles east of the western border of Nevada and near the middle of the state on a north-south line. It is east and southeast of Walker Lake, and northeast of the town of Mina.

The deposits in which the mammalian fauna occurs are spread over an area not less than fifteen miles in diameter, in Ione Valley and in Stewart Valley, but all seem to represent the same formation.

The geology of the Cedar Mountain deposits in which the mammalian fauna occurs has been admirably discussed by J. P. Buwalda.[1] The Tertiary sediments of the Cedar Mountain region are considered by Buwalda to represent a portion of the Esmeralda formation described by Turner[2] from the Silver Peak region immediately to the south.

The Tertiary beds representing the Esmeralda formation in the Cedar Mountain region consist of lacustral accumulations with intercalated beds of terrestrial origin. The formation here has a thickness of not less than one thousand feet.

The lacustral deposits consist in a large part of sandstones with shales, cemented tuffs, conglomerates, limestones, and cherts. The terrestrial beds comprise fanglomerates, sandstones, and pumiceous tuffs. Within the lacustral beds at several localities are lithoid tufa domes similar to those occurring in the Pleistocene deposits of Lake Lahontan.

The Esmeralda formation of the Cedar Mountain region rests in very marked unconformity upon pre-Tertiary series which were greatly deformed and eroded before accumulation of the Esmeralda.

Between the Tertiary beds of the Cedar Mountain region and the older, much disturbed sediments are local rhyolitic and andesitic lavas markedly unconformable upon the older series, and also apparently not conformable with the Esmeralda. So far as observed the rhyolite flows antedate the andesites. Basaltic lavas are known to overlie the Esmeralda beds and seem to rest upon an eroded surface cut in the Esmeralda.

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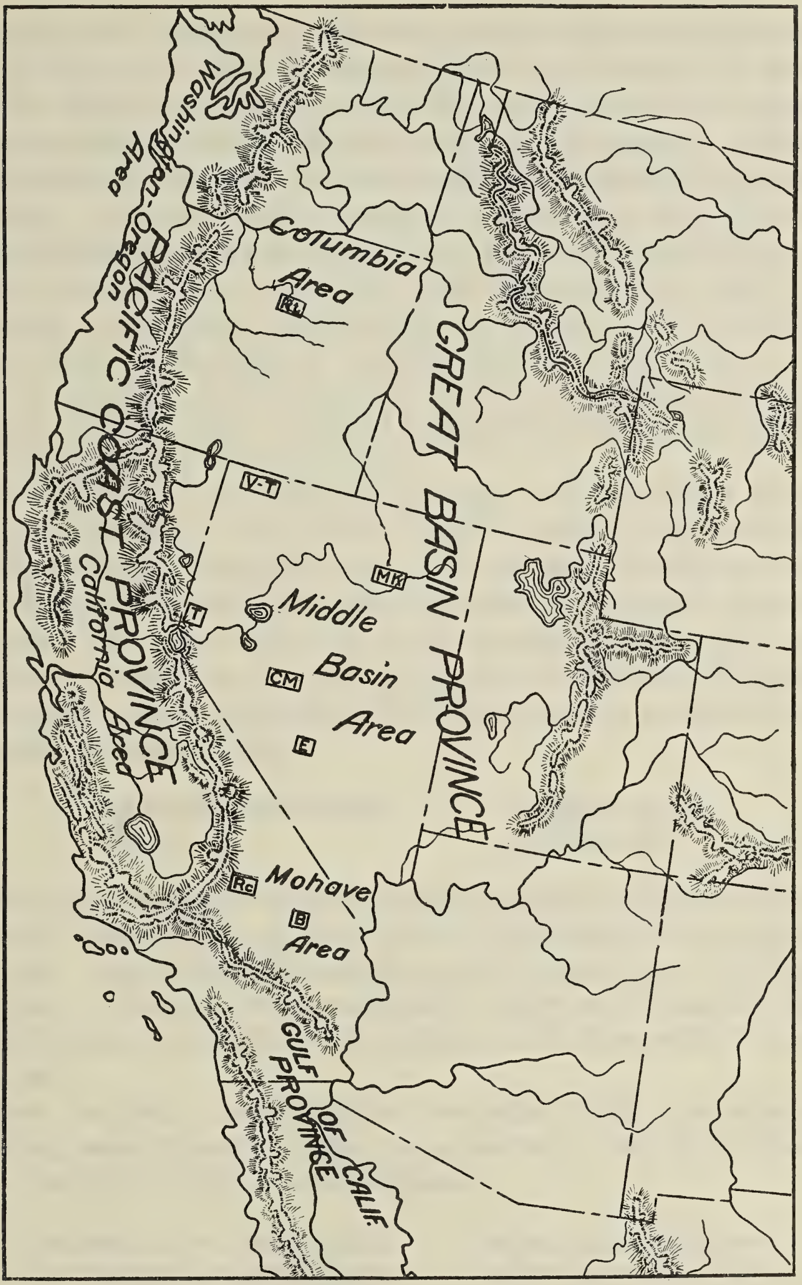
[1] Buwalda, J. P., Univ. Calif. Publ. Bull. Geol. vol. 8, pp. 335–363, pls. 32–38, 1914.

[2] Turner, H. W., Amer. Geol. vol. 25, p. 168, 1900. Also U. S. Geol. Surv. Twenty-first Annual Report, part 2, pp. 192–224, 1900; and Bull. Geol. Soc. Amer. vol. 20, p. 243, 1909.



Outline map of Tertiary provinces in the United States west of the Wasatch Range. CM, Cedar Mountain beds; E, Esmeralda beds; T, Truckee beds; MK, McKnight Miocene; V-T, Virgin Valley and Thousand Creek beds; Rt, Rattlesnake beds and Mascall; Rc, Ricardo beds; B, Barstow beds.

Judging from the amount of movement and erosion in beds above the pre-Esmeralda lavas as compared with that between the lavas and the older series, Buwalda judges that these igneous rocks largely represent lower or middle Miocene time. A post-lacustral andesite which has been deformed and much eroded is considered as probably Pliocene. A basalt resting in apparent unconformity upon the post-lacustral andesite at Table Mountain is considered as late Pliocene.

The Esmeralda formation of the Cedar Mountain region has been subjected to moderate deformation, six or seven low, open folds being noted by Buwalda in crossing Stewart Valley. Since the time of principal deformation the beds have suffered extensive erosion, which has been succeeded by a gentle warping presumed to have taken place in Pleistocene time.

In a sketch of the historical geology of Esmeralda County, Nevada, published in 1902, H. W. Turner[3] refers to lake beds containing abundant fossils four miles west of Black Spring near the line between Esmeralda and Nye counties on the road between Sodaville and Cloverdale. A block containing molluscan and ostracod remains was obtained by Robert Stewart of Sodaville. This specimen was examined by J. C. Merriam who recognized the following molluscan forms:

Sphaerium, near idahoense
Melania?, sp.
Carinifex, sp. *a*
Carinifex, sp. *b*

The *Sphaerium* and two *Carinifex* species resembled forms known from the Truckee beds of Fossil Hill in the Kawsoh Mountains of Nevada. Two species of *Melania* are also known from the Fossil Hill beds. The fauna was considered by Merriam to resemble that of the Truckee, but evidence of similarity to the Esmeralda was not apparent.

From the block containing the molluscan shells a number of ostracods were obtained. These were referred to Dr. R. H. Chapman, who identified the forms as follows:

Ilyocypris, sp. nov., near I. gibba but distinct in important points
Candona, sp. near C. kingsleyi
Candona, sp. probably new
Candona, sp. probably new

---

[3] Turner, H. W., Amer. Geol. vol. 29, p. 268, 1902.

Organic remains representing plants, molluscs, fishes, testudinates, and mammals were obtained in the Cedar Mountain beds by Baker and Buwalda. Remains of trees of considerable size were found in abundance in many localities. About one mile from Stewart Spring a silicified tree trunk not less than six feet in diameter is exposed.

Buwalda lists the following molluscan forms from the Cedar Mountain beds:

Heliosoma cordillerana Hannibal
Viviparus turneri Hannibal
Melania, near sculptilis Meek
Corneocyclas meeki Hannibal

The *Heliosoma* and *Viviparus* are both abundant in the type section of the Esmeralda formation as well as in the Cedar Mountain beds. The Melania-like form is near a species described from the Truckee beds of the Kawsoh Mountain.

Mammalian remains are known from many localities in the Cedar Mountain sediments of Ione Valley and Stewart Valley. They are most abundant in the sandstones and tuffs, but a few specimens have been discovered in angular terrestrial deposits. The material consists commonly of scattered bones, which often give evidence of weathering before burial. Connected parts of the type specimen of *Hypohippus* (*Drymohippus*) *nevadensis* were found in a slab of fine-grained ashy rock containing a large percentage of lime.

Conditions of occurrence indicate that the mammalian remains of the Esmeralda beds in the Cedar Mountain region were buried in part in shore deposits bordering fresh-water lakes, and in part were entombed in purely terrestrial beds. Remains of the smaller land mammals, including all of the rodents, are best known in association with those of fish in shore deposits of a lake. Bones of the larger land mammals occur to some extent in terrestrial beds.

RELATION OF ESMERALDA FORMATION TO CEDAR MOUNTAIN BEDS

In his study of the Cedar Mountain region Dr. Buwalda[4] has shown that the extensive areas of Tertiary sediments examined in Stewart Valley and in Ione Valley can be traced stratigraphically into the Esmeralda formation described by H. W. Turner in the region of Silver Peak to the south. In order to assemble all information concerning the time relations of the Cedar Mountain fauna, it is therefore desirable to include in this paper a brief statement of the geologic relations of the Esmeralda formation at the type locality, and a summary of available information regarding the fauna and flora of the Esmeralda.

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[4] Buwalda, J. P., Univ. Calif. Publ. Dept. Geol. vol. 8, no. 19, 1914.

In the type section of the Esmeralda, Turner describes the formation as consisting of light-colored marls, shales and sandstones, water-worn conglomerates, and Tertiary detrital-slope breccias. The formation was considered to have a thickness of at least 10,000 feet, and was presumed to represent in large part accumulation in a fresh or only slightly saline lake. Remains of plants, fresh-water molluscs, and fish indicated that the beds represented approximately Miocene age.

An interesting succession of lavas described by Turner from the Silver Peak region has definite relation to the Esmeralda sedimentary series and is therefore of unusual importance. The succession is as follows, reading from the latest members to the earliest ones referred to the Tertiary:

7. Dark, fine-grained olivine basalt, which may not be later than the Piper Peak flow.
6. Hypersthene basalt of Piper Peak.
5. Rhyolite-tuff interbedded with sandstones of the Esmeralda formation.
4. Andesite-breccia.
3. Rhyolite-tuff.
2. Andesite-breccia.
1. Older basalt associated with red basal conglomerate of the Esmeralda formation.

The plants of the Esmeralda were examined by F. H. Knowlton[5] who listed the following forms:

Gleichenia? obscura Knowlton
Dryopteris? gleichenoides Knowlton
Spathyema? nevadensis Knowlton
Salix angusta? Al. Br.
Salix vaccinifolia Knowlton
Salix, sp.
Salix?, sp.
Quercus turneri Knowlton
Quercus argentum Knowlton
Ficus lacustris Knowlton
Chrysobalanus pollardiana Knowlton
Cercis? nevadensis Knowlton
Cinchonidium? turneri Knowlton
Rhus nevadensis Knowlton
Indet.

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[5] Knowlton, F. H., U. S. Geol. Surv. 21st Ann. Rep. part II, pp. 209–224, 1900.

Dr. Knowlton considered the flora of comparatively recent age with some species having closely corresponding forms as old as Eocene.

Tree trunks six to eight feet in diameter were found in the Esmeralda beds by Turner.

The fish remains were described by Dr. F. A. Lucas[6] who referred them to a new species of the cyprinoid genus *Leuciscus*. This form, *Leuciscus turneri* Lucas, is not certainly known from localities outside the Silver Peak region, but pharyngeal teeth of cyprinoid fishes are found in the Tertiary beds of the Cedar Mountain region. The fish remains suggested to Dr. Lucas comparatively late age of the Esmeralda, presumably Pliocene rather than Miocene.

Molluscan remains obtained by Turner were examined by J. C. Merriam[7] who did not regard the species as definitely determinative. One of the species was recognized as near *Ancylus undulatus* Meek from the Truckee beds of the Kawsoh Mountains of Nevada. Other species approached the characters of forms referred to the Eocene. The Esmeralda was considered as possibly early Miocene or late Eocene.

As nearly as can be determined from available evidence the Esmeralda formation, and with it the deposits of the Cedar Mountain region, should be correlated approximately with the Truckee beds described by King from the region of the Kawsoh Mountains near the western border of Nevada some distance to the north. As has been shown by Buwalda, the molluscan forms of the Cedar Mountain beds are in part identical with those of the type section of the Esmeralda. There are also elements of similarity between the molluscan fauna of the Cedar Mountain beds and the small fauna listed by King from Truckee. Additional evidence of contemporaneity of the Truckee and Esmeralda is furnished by recent studies of Dr. F. H. Knowlton on a collection of plants obtained by the University of California from Truckee beds near Verdi, Nevada. Dr. Knowlton reports that the strongest affinity of the Verdi flora is with that of the Esmeralda formation. Of twelve species which Dr. Knowlton lists from the Verdi flora, six are apparently identical with or closely related to forms from the Esmeralda flora. The species common to the Truckee and the Esmeralda are the following:

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[6] Lucas, F. A., U. S. Geol. Surv. 21st Ann. Rep. part II, p. 223, 1900.

[7] Merriam, J. C. See Turner, H. W., U. S. Geol. Surv. 21st Ann. Rep. part II, p. 203, 1900.

- Salix angusta Al. Braun
- Salix, sp.
- Rhus? nevadensis Knowlton
- Cercis? nevadensis? Knowlton, smaller
- Ficus lacustris? Knowlton, much smaller
- Chrysobalanus pollardiana Knowlton

Of these the last four species are known only from the Esmeralda and Truckee beds.

COMPOSITION OF CEDAR MOUNTAIN VERTEBRATE FAUNA

- Pisces
  - Salmon-like form
  - Cyprinoid form
- Testudinata
  - Possibly Clemmys
- Aves
  - Nettion carolinense (Gmelin)
  - Marila collaris (Donovan)
  - Querquedula cyanoptera (Vieillot)?
- Carnivora
  - Tephrocyon, near kelloggi Merriam
  - Canid, or mustelid, small
  - Canid, near Aelurodon or Tephrocyon
  - Felid, large, probably machaerodont
  - Felid, small, near Lynx
  - Bassariscus nevadensis, n. sp.
- Rodentia
  - Dipoides, n. sp.
  - Mylagaulus, sp.
  - Aplodontia?, n. sp.
  - Lepus, near vetus Kellogg
- Equidae
  - Hypohippus (Drymohippus) nevadensis Merriam
  - Hypohippus, near osborni Gidley
  - Merychippus, sp.
  - Protohippus?, sp.
- Rhinocerotidae
  - Aphelops?, sp. A
  - Aphelops?, sp. B
- Proboscidea
  - Tetrabelodon, sp.
- Camelidae
  - Procamelus, near gracilis Leidy
  - Pliauchenia?, sp.
- Merycodontidae
  - Merycodus furcatus (Leidy)
  - Merycodus, near necatus Leidy

RELATION OF THE FAUNA TO ITS ENVIRONMENT

A considerable part of the Cedar Mountain fauna comprises types which might inhabit a region of arid or semi-arid climate not greatly different from that of the Cedar Mountain area at the present day. This might be true of the canids, the rabbits, some of the horses, the camels, the merycodonts, and possibly the felids. Other forms, as *Bassariscus*, *Aplodontia*, and *Hypohippus*, are the types that would naturally frequent a moist region or one well provided with trees or brush.

The remains of fish and of fresh-water shells obtained at certain localities in the Miocene of the Cedar Mountain region indicate the presence of fresh-water bodies probably of considerable size. Fossil wood representing trees of large size is common at a number of localities.

From consideration of all biological evidence available it appears that the environment in the Cedar Mountain region during the deposition of the mammal-bearing beds must have been noticeably different from that obtaining there at the present time. The presence of considerable bodies of fresh water, the presence of abundant forest trees, the existence of forest forms like *Bassariscus* and *Aplodontia*, and the relative importance of browsing types with rarity of grazing horses, all suggest a slightly more humid climate, with groves or brush areas such as may occur around the borders of the Great Valley of California at the present time.

STAGE OF EVOLUTION AND RELATIONSHIPS OF THE CEDAR MOUNTAIN FAUNA

Relation of the Cedar Mountain Fauna to the Tertiary Faunas of the Great Basin.—The faunal assemblage obtained in the Cedar Mountain region shows affinity with the Middle Miocene of Virgin Valley, but most nearly approaches the faunal stage of the Barstow Upper Miocene. It is distinctly older than the Ricardo, Thousand Creek, and Rattlesnake. Several differences between the Cedar Mountain and Barstow faunas may be due to geographic variation or may indicate that the Cedar Mountain beds cover a somewhat longer time range, including both older and younger beds than those from which collections have been obtained in the Barstow.

The Cedar Mountain fauna resembles that of the Middle Miocene Virgin Valley in the presence of a *Tephrocyon* near *kelloggi*, *Hypohippus*, *Merychippus*, rhinoceroses, and a *Merycodus* near *furcatus.* It differs from the Virgin Valley and Mascall in the presence of *Dipoides* and *Merycodus necatus;* in the more advanced stage of the horses; and so far as known in the quite advanced stage of the Aplodontia-like rodents, of the camels, and of the merycodont near *M. furcatus.*

Tephrocyon kelloggi, apparently represented in the Cedar Mountain by a portion of a lower carnassial, was described from the Virgin Valley. A similar form is, however, imperfectly known from the Thousand Creek Pliocene. The *Hypohippus* and *Merychippus* of Cedar Mountain are of more advanced types than those of Virgin Valley, and the *Merycodus* near *furcatus* is a larger, heavier form than that of Virgin Valley.

Dipoides is known in the Cedar Mountain beds but has not been found in the Middle Miocene. The Aplodontia-like form in the Cedar Mountain may be a more progressive type than the *Aplodontia* of Virgin Valley. Some of the fragmentary horse remains are much more specialized than any known from the Middle Miocene, and are even relatively advanced for the Barstow Upper Miocene. The total assemblage of forms from the Cedar Mountain certainly seems more advanced than the Middle Miocene of the Great Basin, though it may approach it more closely than does the Barstow fauna.

Compared with the Upper Miocene fauna of the Barstow beds the Cedar Mountain fauna is distinguished especially by the absence of large aelurodons, and by the presence of rhinoceroses with *Merycodus furcatus* as the most common merycodont. Other differences, as the absence of *Merycochoerus* and *Dromomeryx* from the Cedar Mountain, and the absence of certain rodents as *Dipoides* from the Barstow, may be due to the chances of collecting.

Aside from the differences mentioned above, the Cedar Mountain and Barstow faunas have in general a similar aspect. The presence in the Cedar Mountain of a form of *Tephrocyon;* the occurrence in both faunas of a very progressive type of *Hypohippus*, an advanced *Merychippus*, and a protohippine form more specialized than typical *Merychippus*, indicate that the faunas are not widely separate in stage of development. It seems evident that the Cedar Mountain is nearer the Barstow than to any other faunal stage thus far known in the Great Basin, and is therefore probably of Upper Miocene age.

The presence of rhinoceroses and of *Merycodus furcatus* in the Cedar Mountain in the same association as in the Santa Fe Upper Miocene, whereas they are both absent from the Barstow, may be due to geographic variation or difference in environment. It is possibly due to slightly earlier stage of evolution of the Cedar Mountain fauna. The collections from the Barstow beds are the largest thus far brought together in the southwestern portion of the Great Basin, but as yet neither rhinoceroses nor *Merycodus furcatus* appears in the abundant material.

Compared with the Ricardo fauna, the mammals of the Cedar Mountain beds lack the advanced aelurodons, while the horses and camels are generally much more primitive. The presence of *Dipoides*, *Mylagaulus*, and one rather advanced horse in the Cedar Mountain beds would seem to show a relatively advanced stage; but *Dipoides* and *Mylagaulus* are both known in the Upper Miocene of America, although not as yet obtained in the Barstow, while the progressive horse may not be more specialized than one form in the Barstow beds.

Unless it be true that there is in the Cedar Mountain region a series of beds somewhat younger than those from which the principal fauna has been obtained, there is good reason for considering the fauna of these beds as considerably older than that of the Ricardo.

In comparison with the Thousand Creek and Rattlesnake Pliocene, the Cedar Mountain shows a wide difference in the horses and camels. The presence of *Hypohippus* and *Merychippus* with two species of *Merycodus* in the Cedar Mountain fauna indicates a much earlier stage than that of either the Thousand Creek or Rattlesnake, before the deposition of which these genera had disappeared.

TABLE ILLUSTRATING RELATIVE AGE OF THE CEDAR MOUNTAIN FAUNA COMPARED WITH OTHER FAUNAS OF THE GREAT BASIN PROVINCE

Time scale		Columbia and Middle Basin areas	Mohave area
Pliocene	Upper		
	Middle		
	Lower	Thousand Creek Rattlesnake	Ricardo
Miocene	Upper	Cedar Mountain	Barstow
	Middle	Mascall	
	Lower	Columbia Lava	

Relation of Cedar Mountain Fauna to that of the American Tertiary East of the Great Basin.—The age of the Cedar Mountain fauna is best determined when this assemblage is considered in conjunction with other like faunas of the Great Basin region. Considering the similarity of this fauna to that of the Barstow beds, and the relation of the latter to the Upper Miocene Santa Fe fauna of northern New Mexico, there can be little doubt of the relation of the Cedar Mountain to the Upper Miocene.

Compared directly with the Santa Fe fauna, the Cedar Mountain mammals in some respects show a closer resemblance than do those of the Barstow. While the large aelurodons of the Santa Fe are not as yet known in the Cedar Mountain, there is a noticeable similarity in the camels, in the merycodonts, and in the presence of rhinoceroses, the last group being absent from the Barstow.

The Cedar Mountain fauna resembles that of the Upper Miocene or Lower Pliocene Republican River beds of the northwestern Kansas to a considerable extent, but seems less advanced in the canids, which are exclusively large specialized forms at Republican River. The Snake Creek fauna of western Nebraska also shows an interesting similarity in the presence of *Tephrocyon*, a Bassariscus-like form, *Dipoides*, *Mylagaulus*, rhinoceroses, merycodonts, advanced camels, *Hypohippus* of an advanced stage, and *Merychippus*. The presence of numerous advanced horses of the *Neohipparion*, *Protohippus*, and *Pliohippus* types, with the introduction of true antelopes in *Neotragocerus*, indicates that the Snake Creek is younger than the Cedar Mountain, but the difference is evidently not measured by the lapse of more than half of a geological period.

On the whole there seems good reason for considering the Cedar Mountain fauna as near the Barstow and the Santa Fe in stage, and somewhat older than the Republican River and Snake Creek.

DESCRIPTION OF THE FAUNA

PISCES

A considerable number of fragmentary fish remains consisting of isolated vertebrae and parts of head bones were found at several localities. They include at least two forms, one near the salmon and the other too imperfect for determination. Professor J. O. Snyder of Stanford University, who examined the collection of fish remains from the Cedar Mountain beds writes concerning them as follows:

> "I am returning the fossil fish remains today and I am unable to say anything further about them than that they appear to belong to some salmon-like form and

are certainly not members of other families now living in the Great Basin. There may be more than one species represented. Dr. Jordan and others here could offer nothing more in way of suggestion."

TESTUDINATA

A few fragments of plates found in the deposits at locality 2027 in association with fish remains and with fresh-water gastropods may represent a type near *Clemmys*. The material is too imperfect for satisfactory identification. The form represented by the material may be a fresh-water type. No remains of land tortoises such as appear in the Barstow and Ricardo faunas are as yet certainly known from the Cedar Mountain beds.

AVES

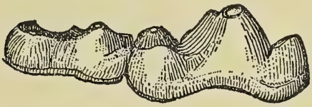
A few fragmentary bird remains obtained in the Cedar Mountain region by Baker and Buwalda are interesting as representing some of the very few avian remains known from the West-American middle Tertiary.

Dr. L. H. Miller has kindly examined the material available and reports upon it as follows:

> "Professor J. C. Merriam of the University of California has recently placed in my hands a small collection of bird remains collected in the Cedar Mountain beds of Western Nevada by Messrs. Baker and Buwalda in the summer of 1912.
>
> "The material was fragmentary and somewhat worn, hence the identity in some cases is merely approximated. The specimens all represent anserines which at present inhabit fresh-water bodies or enclosed bodies of brackish or salt water. These bodies of water may be of most ephemeral nature and sometimes highly charged with alkaline salts. The presence of the species in the deposits of Nevada would therefore have little bearing on the question of climatic conditions during the deposition of these beds.
>
> "The remains are listed as follows:
>
> Distal end of humerus—*Nettio carolinense* (Gemlin)
> Proximal end of humerus—Near *Marila collaris* (Donovan)
> Distal end of tibia—*Marila collaris* (Donovan)
> Proximal end of ulna—Near *Querquedula cyanoptera* (Vieillot)
> Fragments of furcula—Indeterminate."

CARNIVORA

Carnivore remains are imperfectly represented in the collection from the Cedar Mountain region, but evidently include a considerable variety of forms. There are probably not less than six or seven species in the small amount of material available. Of these forms, three are canids, two felids, one possibly a mustelid, and one evidently a procyonid. The Carnivora do not evidence a very close relationship with those of any other fauna. One of the canids, *Tephrocyon* near *kelloggi*, is almost identical with a species described from the Virgin Valley Middle Miocene of northern Nevada. Another type is near the stage of development of the aelurodons of the late Miocene or early Pliocene.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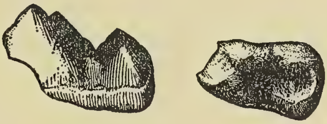
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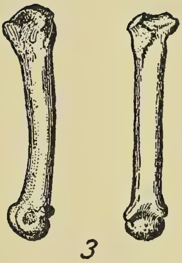
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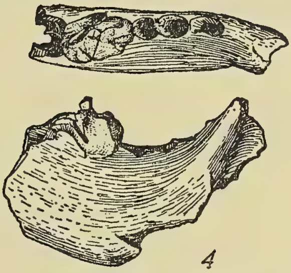
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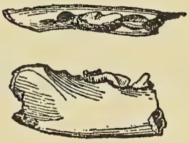
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FIG. 1. *Tephrocyon kelloggi* Merriam. M_1 and M_2 of type specimen, × 1½. Virgin Valley beds, Virgin Valley, Nevada.

FIGS. 2*a* AND 2*b*. *Tephrocyon*, near *kelloggi* Merriam. M_1, × 1½. Cedar Mountain beds, Stewart Valley, Nevada. Fig. 2*a*, lateral view of M_1; fig. 2*b*, superior view of heel with protoconid and metaconid of M_1.

FIG. 3. Metacarpal III, possibly canid. No. 22289, × ½. Cedar Mountain beds, Stewart Valley, Nevada.

FIG. 4. *Aelurodon* or *Tephrocyon*, sp. Portion of mandible with broken carnassial, no. 19782, × ½. Cedar Mountain beds, twenty-eight miles northeast of Mina, Nevada.

FIG. 5. Mustelid?, indet. Portion of mandible, no. 19781, × ½. Cedar Mountain beds, Stewart Valley, Nevada.

TEPHROCYON, near KELLOGGI Merriam

A portion of a lower carnassial no. 19767 (figs. 2*a* and 2*b*) from Stewart Valley represents a species near or identical with *Tephrocyon kelloggi* of the Virgin Valley Miocene of northern Nevada. The fragment present is almost identical in form with the lower carnassial of the type specimen. Very slight differences are due mainly to the difference in stage of wear. The correspondence in form includes length of heel, size of metaconid, position and form of the small inner and outer tubercles between trigonid and talonid, the presence of a faint ridge of the cingulum on the outer side of the heel, and the development of a faint ridge on the outer portion of the posterior end of the heel. The measurements are nearly identical.

Comparative Measurements

	No. 19767	Type T. kelloggi
M_1, anteroposterior diameter of heel on inner side	4.3 mm.	4.1
M_1, greatest transverse diameter of heel	6.5	7

CANID, AELURODON?, sp.

A portion of the mandible, no. 19782 (fig. 4), of a large canid represents a form near *Aelurodon*, or *Tephrocyon*. Of the Great Basin forms the species seems nearest to an *Aelurodon* from the Ricardo fauna.

CANID, sp.

Several astragali (no. 19780) represent a small canid.

MUSTELID?, sp.

A portion of a small mandible no. 19781 (fig. 5) represents a Canis-like form with slender but thick jaws, small M_1, very small and one-rooted M_2, and no M_3. It presumably represents an unknown mustelid in the Cedar Mountain fauna.

FELID, sp. A

A small phalangeal element (no. 19800, fig. 9), of a felid form from Stewart Valley, locality 2027, represents a cat of approximately the dimensions of the existing wildcat. It is uncertain whether it represented the feline or the machaerodine division of the family.

FELID, sp. B

Phalangeal elements no. 19769 and 19700 (figs. 7 and 8) represent felids near the size of the puma. A slender, somewhat catlike metapodial, no. 22289 (fig. 3), may not represent a felid form.

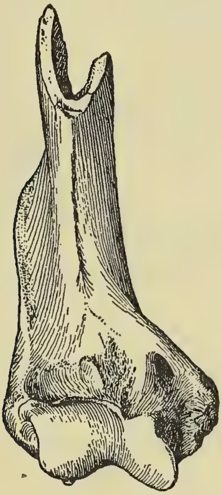
A humerus, no. 19765 (fig. 6) near the size of that in the Recent puma possibly belongs to one of the felid types mentioned above. The supinator ridge is much heavier than in the puma.

MEASUREMENTS OF HUMERUS No. 19765

Greatest width across distal end	54	mm.
Least anteroposterior diameter of trochlea	17.3	

BASSARISCUS NEVADENSIS, n. sp.

A portion of the mandible with the carnassial and premolars (fig. 10) from Stewart Valley, Nevada, locality 2027, represents a form almost indistinguishable from the Recent miners cat of California. The dimensions of the teeth are almost identical with those of two Recent California specimens. In comparison with the modern *Bassariscus astuta* the fossil specimen (no. 19768) shows M_1 very slightly shorter anteroposteriorly, and the mandible somewhat higher and thicker. In the fossil form the posterior border of P_4 is less distinctly concave and the posterior cusp is relatively a little less prominent. The posteroexternal angle of the hypoconid of M_1 in the fossil specimen is more distinctly angular than in the Recent specimens of *B. astuta* examined.



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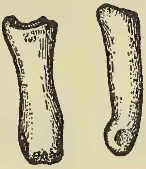

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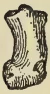

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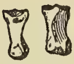

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FIG. 6. Felid, indet. sp. B. Portion of humerus, no. 19765, × ½. Cedar Mountain beds, Stewart Valley, Nevada.

FIGS. 7 AND 8. Felid, indet. sp. Phalanges, nos. 19769 and 19700, × ½. Cedar Mountain beds, Ione Valley, Nevada.

FIG. 9. Felid, indet. sp. A. Phalanx, no. 19800, × ½. Cedar Mountain beds, Stewart Valley, Nevada.

A satisfactory comparison of the specimen from Stewart Valley with *Probassariscus antiquus* from the Pliocene of Snake Creek, Nebraska, and the Miocene of Virgin Valley, is not possible, as M_2 is absent. It may be that this form possessed a paraconid on the tubercular molar as in *Probassariscus*, but this cannot be determined until more material is obtained. The mandible seems noticeably heavier in *Probassariscus* than in specimen no. 19768, and there is a slight difference in the proportions of the lower carnassial.

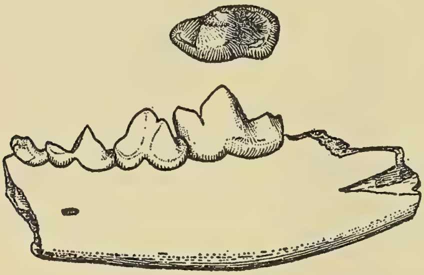


FIG. 10. *Bassariscus nevadensis*, n. sp. Lower jaw with dentition, no. 19768, × 2. Cedar Mountain beds, Stewart Valley, Nevada.

There can be little doubt that the *Bassariscus* form from the Cedar Mountain region inhabited a territory that was fairly well watered and partly wooded. The climatic conditions must have been quite different from those obtaining in the Cedar Mountain region at the present time.

MEASUREMENTS

	Cedar Mt. specimen (*a*)	B. astuta Recent (*b*)	B. astuta (*c*) Recent	P. antiquus matthewi (*d*) Virgin Valley
P_3, anteroposterior diameter	4.3 mm.	4.6	4.3	...
P_3, transverse diameter	2.2	2.3	2.2	...
P_4, anteroposterior diameter	4.9	5	5	5.2
P_4, transverse diameter	2.4	2.5	*ap* 2.4	2.7
M_1, anteroposterior diameter	7.1	7.3	7.6	6.8
M_1, transverse diameter across metaconid	3.8	3.9	3.8	3.8
M_1, transverse diameter of heel	3.2	3.3	3.4	3.7
M_1, anteroposterior diameter from base of protoconid to posterior end	2.4	2.4	2.4	2.8
Depth of lower jaw below M_1	6.9	6	6.7	7.8

(*a*) No. 19768 (*b*) No. 8800 (*c*) No. 8799 (*d*) No. 12539

ap, approximate.

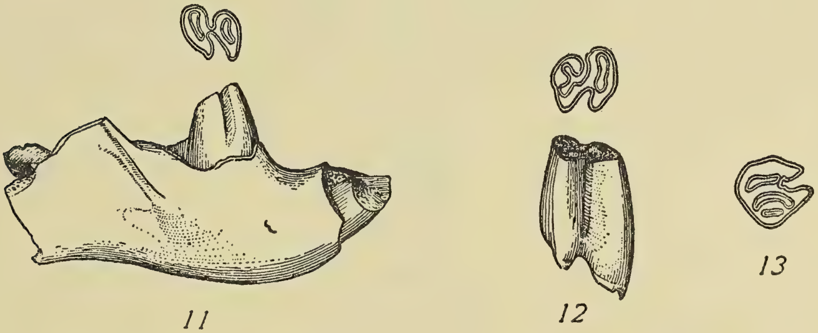
Rodentia

DIPOIDES, near TORTUS (Leidy)

Several specimens from Stewart Valley (locality 2027) represent a form near this species. (See figs. 11 to 13.)

Measurements

	No. 19802	D. tortus	D. curtus
Length of lower premolar series	17.5	19.5	14.5
P_4, greatest anteroposterior diameter	6.5	5.5	4.6
P_4, greatest transverse diameter	4.8	4.7	3.8
Depth of jaw below M_2	9.5	14	8.5



Figs. 11 to 13. *Dipoides*, near *tortus* (Leidy). Cedar Mountain beds, Stewart Valley, Nevada.

Fig. 11, mandible with P_4, no. 19802, × 2; fig. 12, P_4, no. 19804, × 2; fig. 13, P^4, no. 19803, × 2.

MYLAGAULUS?, sp.

A fragment of a large molar (no. 19801) from Stewart Valley (locality 2027) represents a mylagaulid form, but the tooth is too imperfect for specific determination. The specimen does not appear to differ distinctly from the fourth premolar of *Mylagaulus*, and may be referred provisionally to that genus.

APLODONTIA?, n. sp.

A single upper premolar, no. 19798 (fig. 14), from Stewart Valley (locality 2027), represents a rodent evidently belonging in the group of the Aplodontidae, but not corresponding exactly to any form known to the writer. It shows resemblance both to *Meniscomys* and to *Aplodontia*, but does not duplicate the characters of either.

The crown of the tooth is worn down close to the large, very slightly divergent roots upon which it is supported. On the occlusal face there are at least four enamel lakes, which extend down almost to the lower end of the crown.

The form of the crown, taken with the depth and the tendency to cylindrical form of the enamel lakes, suggests that the normal unworn crown was short hypsodont.

The character of the tooth resembles in general that of *Aplodontia*, but differs in the shortness of the crown or in the depth of the enamel lakes, as also in the number of enamel lakes. In minor details of cross-section and in size, specimen 19798 would differ from any *Aplodontia* species known to the writer. In the Recent aplodontias, and in *Aplodontia alexandrae* of the Virgin Valley Middle Miocene, the crown of P^4 is long hypsodont, and the bottoms of the enamel valleys at the top of the crown disappear in early wear. In specimen 19798, the enamel valleys reach the lower end of the crown. Either the tooth was much shorter than in true *Aplodontia* or the enamel valleys were deeper.

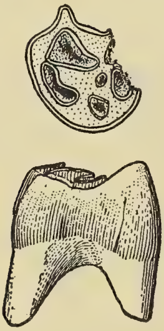


Fig. 14. *Aplodontia?*, n. sp. P^4, anterior and occlusal views, no. 19798, × 4. Cedar Mountain beds, Stewart Valley, Nevada.

On specimen 19798, there are four enamel lakes shown on the occlusal surface. Two are on the outer half of the surface, and two on the inner half. In a Recent *Aplodontia* a fourth upper premolar just about to come into use shows two external valleys, which apparently correspond to the enamel lakes seen in slightly worn teeth. A very shallow valley runs transversely over the tooth from the mesostyle to the inner border. In *Aplodontia alexandrae* an unworn P^4 shows a form similar in general to that of the Recent species, with the exception that the valley extending across the tooth from the mesostyle to the inner border is divided into outer and inner depressions separated by a wall. The outer of these two valleys is apparently deep, the inner valley is relatively shallow. A somewhat worn specimen of *Aplodontia alexandrae* shows on P^4 three enamel lakes which apparently correspond to the anteroexternal, posteroexternal and internal valleys. Three of the enamel lakes of specimen 19798 correspond approximately to the three seen in P^4 of *Aplodontia alexandrae.* The anterior and posterior lakes apparently correspond to the large lakes in Recent *Aplodontia.* The anterointernal lake seems to correspond to the anterointernal lake of worn teeth of *A. alexandrae,* or to the large shallow valley in the unworn specimen. Two very small canals in specimen 19798 may represent the middle outer valley next the mesostyle in *A. alexandrae,* though this must remain doubtful. The relation of the posterointernal lake of specimen 19798 to the valleys of *A. alexandrae* is doubtful. This lake occupies the position of a posterointernal valley in *Meniscomys,* which is presumed to be the ancestor of *Aplodontia.*

The writer considered the possibility that no. 19798 represents a milk premolar of a form like the Recent *Aplodontia,* and was fortunate in finding in the California Museum of Vertebrate Zoology a specimen with Dpm^4 well preserved. Dpm^4 of the Recent *Aplodontia* resembles specimen 19798 in the reaching down of the enamel valleys almost to the bottom of the relatively short crown, but the number of the enamel lakes does not correspond to that in no. 19798, and the roots of Dpm^4 of the Recent form are much more divergent than in the fossil specimen. Divergence of the roots seems to be a necessary character in the Dpm^4 in order to permit P^4 to come down between the roots.

Though specimen 19798 is evidently nearest to *Aplodontia,* it shows an interesting resemblance to *Meniscomys.* In *Meniscomys* there are four valleys which are more pronounced than any other features of the occlusal surface, and a slight elongation of the crown with deepening of the valleys might produce in wear a section quite similar to that in specimen 19798.

The less rounded anterior side of the tooth in no. 19798 is more as in *Meniscomys,* as are the short crown and the non-divergent roots.

The exact relationships of this form are uncertain, more than that it quite certainly belongs with the Aplodontidae. It apparently lies between *Aplodontia* and *Meniscomys*, but is much nearer *Aplodontia*. Unless the specimen should be found to represent Dpm⁴ of an unknown species related to *Aplodontia alexandrae*, it probably pertains to a genus intermediate between *Meniscomys* and *Aplodontia*.

Measurements

	No. 19798	Aplodontia rufa	Aplodontia alexandrae
P^4, greatest anteroposterior diameter	*ap* 4.2 mm.	5	3.5
P^4, greatest transverse diameter	3.9	5	4
P^4, height of portion of crown remaining	2.8		

ap, approximate.

LEPUS, near VETUS Kellogg

Two teeth from the collection at Stewart Valley, locality 2027, represent a leporid form which is near *Lepus vetus*, found in the Virgin Valley Miocene and Thousand Creek Pliocene of Nevada, but is probably specifically different from that form.

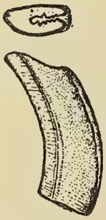


Fig. 15. *Lepus*, near *vetus* Kellogg. Cheek-tooth, no. 19799, × 2. Cedar Mountain beds, Stewart Valley, Nevada.

The teeth examined are slightly curved. The convex inner face shows a deep fold, the borders of which exhibit numerous secondary plications (fig. 15). The anterior and inner faces are enamel-covered; the outer face and a portion of the anterior one are naked. The enamel of the inner face is covered with a layer of cement filling the fold on this side. The outer face is beveled obliquely. The beveled surface is faintly grooved longitudinally.

Measurements of No. 19799

Length of crown	9.7 mm.
Anteroposterior diameter	2
Transverse diameter	3.7

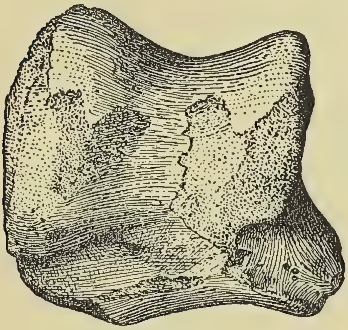
The form represented by the specimen measured is considerably smaller than the type of *Panolax sanctaefidaei* from the Upper Miocene of New Mexico, and is quite certainly specifically distinct.

RHINOCEROTIDAE

Two forms known by astragali representing this group are found with the Cedar Mountain fauna, but the systematic position within the group is doubtful in both cases. In addition to these forms a number of tooth fragments and several foot bones (no. 22284) from near locality 2028 about four miles north of Stewart Spring represent a large rhinoceros with short feet approaching the *Teleoceras* type.

APHELOPS?, sp. A

A large astragalus, no. 19824 (fig. 16), from locality 2026, in Stewart Valley, represents a rhinoceros with a form of tarsus similar to that in *Aphelops*. This astragalus is near the size and form seen in a specimen from High Rock Cañon in northwestern Nevada.



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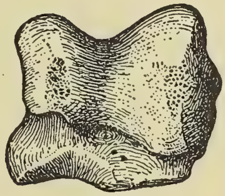

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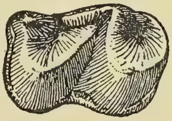

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FIG. 16. *Aphelops?*, sp. A. Astragalus, no. 19824, $\times \frac{1}{2}$. Cedar Mountain beds, Stewart Valley, Nevada.

FIG. 17. *Aphelops?*, sp. B. Astragalus, no. 19822, $\times \frac{1}{2}$. Cedar Mountain beds, Nevada.

FIG. 20. *Hypohippus*, near *osborni* Gidley. M_2?, occlusal view, no. 19763, natural size. Cedar Mountain beds, Stewart Valley, Nevada.

APHELOPS?, sp. B

An astragalus, no. 19822 (fig. 17), with an anteroposterior diameter about one half that of no. 19824, seems to represent another rhinoceros possibly near the *Aphelops* type. This specimen is similar in size and form to a specimen 1201 from locality 871, presumably from the Upper John Day Oligocene of the eastern Oregon. The cuboid facet is a little large and is flatter at the lower end in the Cedar Mountain specimen. The inner facet for the astragalus is considerably smaller in the Cedar Mountain specimen.

Equidae

Remains of horses are relatively rare in the Cedar Mountain beds, and only a very few teeth and isolated limb-bones have been obtained. Judging by the relative quantity of remains, the horse fauna seems to have been overshadowed in importance by the camels in this region during deposition of the Cedar Mountain beds. The forms known thus far include *Hypohippus* (*Drymohippus*) *nevadensis*, a species near *Hypohippus osborni* but possibly identical with the first-mentioned form, a *Merychippus* species near the *M. calamarius* forms of the Barstow fauna, and a few fragments indicating the presence of a form more advanced than the common species of the Barstow. This last form may be comparable to the most advanced type of the Barstow resembling *Protohippus* or *Pliohippus* and rarely seen in that fauna.

It is perhaps significant that the browsing type, *Hypohippus* or *Drymohippus*, plays a relatively important part in the Cedar Mountain fauna as it is known at this time. If horses are relatively rare in Miocene deposits in which ungulates are fairly represented, and if the *Hypohippus* type represents a relatively large percentage of the horses present, one unavoidably considers the possible influence of environment in determining range and representation of the group. Absence of grazing horses, as *Merychippus* and presence of browsing forms would be due to absence of grass or to predominance of brush. The physical conditions under which the Cedar Mountain beds were deposited do not suggest a predominantly forested or brushy region, though both trees and brush were presumably present. It may be that grazing was relatively better elsewhere, and that *Merychippus* was abundant in regions not far distant.

HYPOHIPPUS (DRYMOHIPPUS) NEVADENSIS Merriam

Hypohippus (*Drymohippus*) *nevadensis* Merriam, Univ. Calif. Publ. Bull. Dept. Geol. vol. 7, p. 420, 1913.

Type specimen no. 21056, University of California Collections in Vertebrate Palaeontology. From the Cedar Mountain beds, in Stewart Valley, twenty-four miles northeast of Mina, Nevada.

Characters much as in *Hypohippus*, but metaloph of milk molars not connected with ectoloph.

Type specimen a small portion of the skull with three milk molars, portions of all four limbs, and a number of scattered fragments of other skeletal parts.

Skull and Dentition.—All that remains of the skull consists of a portion of the lower region of the cranium. The part of the cranium present exhibits little of significance.

The dentition of the type skull shows three well-preserved cheek-teeth. The incisors are not present. The cheek-teeth represent the milk dentition with Dm^4 just coming into function. The teeth represent an animal larger than any of the known forms of *Hypohippus*, but approaching in size *Hypohippus affinis*, the largest described species. They are absolutely larger than the permanent premolars of *H. osborni*, and larger than the milk molars of the type specimen of *H. affinis*. The excess in dimensions is evident in both the anteroposterior and transverse diameters.

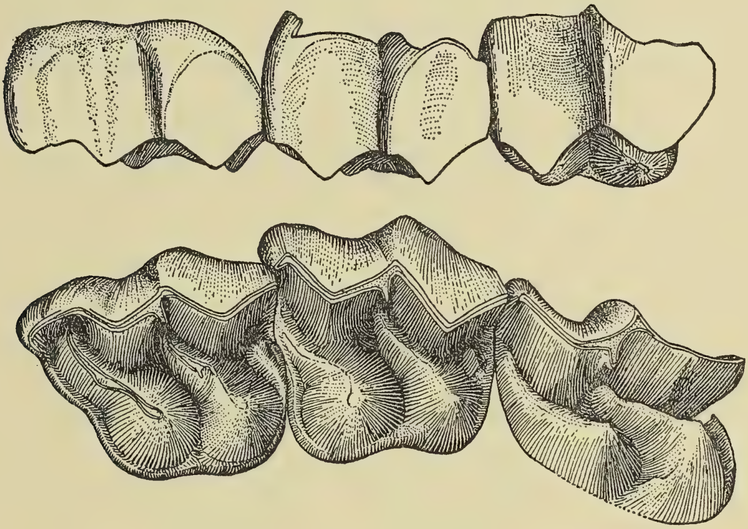


Fig. 18. *Hypohippus* (*Drymohippus*) *nevadensis* Merriam. Upper milk molars, outer and occlusal views, no. 21056, natural size. Cedar Mountain beds, Nevada.

In form and pattern the milk molars resemble in general the permanent dentition of *Hypohippus osborni.*

The principal difference between the Nevada specimen, no. 21056, and *Hypohippus osborni* is found in the separation of the outer end of the metaloph from the ectoloph. In none of the milk molars of the Nevada specimen is the summit of the outer end of the metaloph connected with the ectoloph. In Dm^2 and Dm^3 the base of the metaloph scarcely reaches the base of the ectoloph. In each of these teeth there is a small transverse ridge or tubercle pointing inward from the ectoloph at the posterior end of the paracone crescent. This transverse prominence arising from the ectoloph extends inward near the outer end of the metaloph but fails to meet that ridge. The outer end of the metaloph tends to swing a little in front of the inner transverse prominence of the ectoloph.

The inner transverse prominences arising from the ectoloph attain their greatest elongation or height near the summit of the ectoloph, and rapidly diminish in height as they extend toward the base of the tooth. On Dm^4 the transverse prominence consists of two small tooth-like projections. On the longer or lower of these points the diameter, parallel with height of the tooth crown, is not more than twice the anteroposterior diameter. The second projection, situated farther toward the base of the ectoloph, is an exceedingly small tubercle. The smaller projection does not reach the bottom of the valley between the metaloph and the metacone crescent. On Dm^3 the inner transverse prominence of the ectoloph is very small, and is situated near the crest of the ectoloph. On Dm^2 the prominence is higher, but is reduced rapidly at the proximal end and does not connect with the metaloph.

The Nevada form seen in specimen 21056 represents a type with dentition in general close to that of *Hypohippus*, but distinguished especially by the less advanced stage of evolution of the metaloph in the temporary molars.

Limbs.—Portions of both the anterior and posterior limbs (fig. 19*a* and 19*b*) exhibit some of the essential characters. The general structure and proportions of the parts of the extremities preserved are near those of *Hypohippus*. The lateral digits and their ungual phalanges are relatively large, and were evidently functional. The first and second phalanges of the median digit are relatively shorter and wider than in the *Merychippus* forms of the Miocene. The ungual phalanx of the median digit is broad, and the lateral wings show a stage of development at least as advanced as in *Hypohippus*. Metacarpal three shows a distinctly oblique lateral facet for articulation with the unciform. In metatarsal three there seems to be a very small and quite oblique facet for the cuboid. In general the limb structure resembles that of *Hypohippus*.

COMPARATIVE MEASUREMENTS OF DENTITION

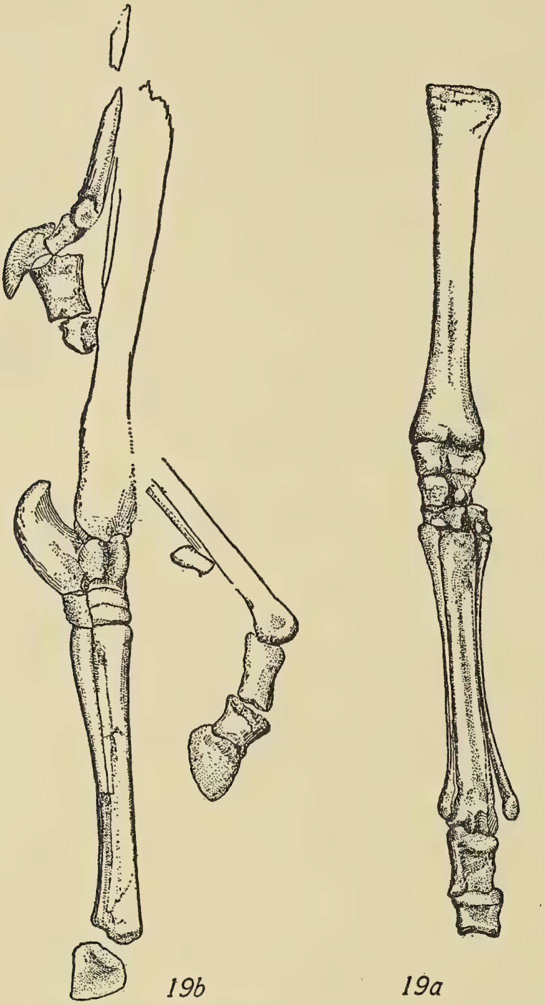
	Milk dentition		Permanent dentition	
	H. nevadensis No. 21056	H. affinis Type specimen	H. osborni	H. equinus
Dm^2, anteroposterior diameter along outer border	33 mm.	....	P^2 27.3	25
Dm^2, greatest transverse diameter	29	....	P^2 26	25
Dm^3, anteroposterior diameter along outer border	31.8	....	P^3 25.4	25
Dm^3, anteroposterior diameter measured through protoconule and hypostyle	29	....	P^3 24	22 *b*
Dm^3, greatest transverse diameter	30.5	....	P^3 30	27
Dm^4, anteroposterior diameter along outer border	31.9 *ap.*	28.5 *ap.*	P^4 30	25
Dm^4, anteroposterior diameter measured through protoconule and hypostyle	....	26.7 *a*	P^4 25	22 *b*
Dm^4, greatest transverse diameter	31.4	29	P^4 30	26

a, measurements from J. Leidy's figure of type specimen.
b, from W. B. Scott's figures of type specimen.
ap, approximate.

MEASUREMENTS OF LIMB ELEMENTS, No. 21056

Radius, greatest length of shaft	241 mm.
Radius, least width of shaft	25
Metacarpal II, greatest length	190
Metacarpal III, greatest length	192
Metacarpal III, width of distal end, approximate	28.5
Phalanx I, digit III of anterior extremity, greatest length	40
Phalanx I, digit III of anterior extremity, greatest width	30
Phalanx II, digit III of anterior extremity, greatest length	30
Phalanx II, digit III of anterior extremity, greatest width	31
Metatarsal III, greatest length	203
Metatarsal IV, greatest width at proximal end	17
Phalanx I, lateral digit (hind foot?) greatest length along superior side	23.5
Phalanx III, lateral digit (hind foot?) length along superior side	35

Relationships.—The form represented in specimen no. 21056, resembles *Hypohippus* in the characters of the limbs and in general form of the cheek-teeth. It differs from *Hypohippus* in the separation of metaloph and ectoloph in the milk dentition. It is uncertain whether the permanent dentition of this species is represented in any of the collections from the Great Basin region. The total characters, so far as known, indicate that the species is much nearer to *Hypohippus* than to any other group, and excepting the separation of metaloph and ectoloph it is not clearly distinguished from that genus. The gap between this form and typical *Hypohippus* seems less than the spaces between other anchitheriine genera. The new subgenus, *Drymohippus*, proposed to include this form,



Figs. 19*a* and 19*b*. *Hypohippus* (*Drymohippus*) *nevadensis* Merriam. No. 21056, × ⅕. Cedar Mountain beds, Nevada.
Figs. 19*a*, anterior limb; 19*b*, posterior limb.

bears the characters of *Hypohippus* excepting in the separation of metaloph and ectoloph in the milk dentition. Later investigations may add other distinctive characters.

HYPOHIPPUS, near OSBORNI Gidley

A lower molar (no. 19763, fig. 20) from locality 2027 represents a species of *Hypohippus* near the form found in the Middle Miocene of Virgin Valley in northern Nevada. This species is apparently nearer to *Hypohippus osborni* than to *H. equinus* or to *H. affinis*. Specimen no. 19763 is almost identical in dimensions with the Virgin Valley form. The tooth resembles the Virgin Valley species in form excepting in the character of the entostylid, which is relatively very weak in no. 19763. It is not improbable that additional material may show that the Nevada species is distinct from those previously described from other regions.

Comparative Measurements

	No. 19763	No. 12587 Virgin Valley	Hypohippus osborni	H. equinus	H. affinis
M_1, anteroposterior diameter..	....	22 mm.	23.8	23	28.5
M_1, transverse diameter......	....	16	18.1	14	20
M_2, anteroposterior diameter..	20.7?	21	23.5	22	....
M_2, transverse diameter......	14.3?	14.4	16.2	12	....

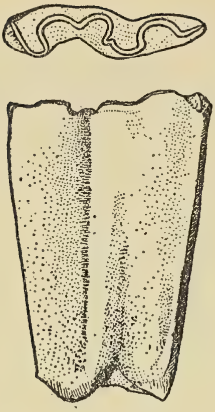
Two fragments of upper molars evidently represent *Hypohippus*.

MERYCHIPPUS, sp.

The proximal phalanges of the protohippine horse (figs. 26 and 27) from locality 2027 represent a type almost exactly similar to proximal phalanges of *Merychippus* from the Middle Miocene of Virgin Valley. They are also very close in form to phalanges of *Merychippus* from the Barstow Miocene. The Cedar Mountain specimens show a little less median constriction than the average specimens from the Barstow fauna, and in this respect are more like the Virgin Valley form.

A calcaneum (no. 21481) from locality 2027 represents a Merychippus-like species probably identical with that shown in the proximal phalanges.

The proximal end of a slender metatarsal (figs. 28*a* and 28*b* no. 21482) shows well-developed cuboid and mesocuneiform facets. It differs from *Merychippus*, and from the larger forms of the Ricardo referred to *Hipparion* and *Pliohippus*. The mesocuneiform facet is large, but is somewhat smaller than the cuboid facet. Both cuboid and mesocuneiform facets are nearly flat, or in the plane of the ecto-



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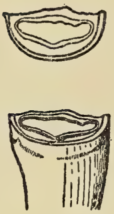

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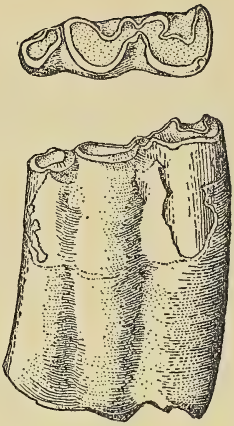

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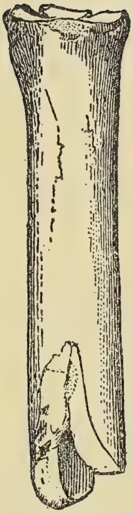

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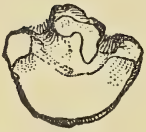

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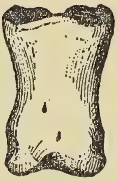

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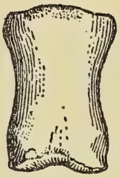

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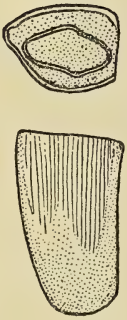

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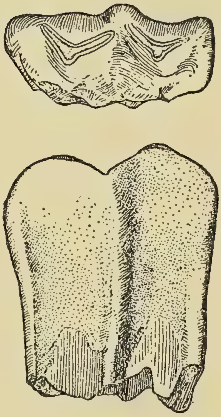

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Figs. 21 and 22. *Merychippus*, sp. Fig. 21, M_3, external and occlusal views, no. 19825, natural size; fig. 22, incisor, inner and occlusal views, no. 22287, natural size. Cedar Mountain beds, Nevada.

Figs. 23 and 24. *Protohippus?*, sp. Fig. 23, inner portion of lower molar, no. 21483, natural size; fig. 24, outer portion of upper cheek-tooth, no. 22286, natural size. Cedar Mountain beds, Nevada.

Fig. 25. *Merychippus?* or *Hipparion?*. Incisor, external and occlusal views, no. 22285, natural size. Cedar Mountain beds, Ione Valley, Nevada.

Figs. 26 and 27. *Merychippus*, sp. Proximal phalangeal elements, × ½. Fig. 26, no. 19823; fig. 27, no. 22291. Cedar Mountain beds, Stewart Valley, Nevada.

Figs. 28*a* and 28*b*. *Merychippus?*, sp. Proximal end of metatarsal III, no. 21482, × ½. Cedar Mountain beds, Stewart Valley, Nevada.

cuneiform facet. This specimen may represent *Hypohippus*. It differs from that genus in that the cuboid facet is nearly in the plane of the ectocuneiform facet, while in *Hypohippus*, as known to the writer, the cuboid facet slopes at an angle of near 45° from the plane of the ectocuneiform facet. In *Pliohippus* there is a distinct mesocuneiform facet, but the cuboid articulation is relatively larger.

A lower molar (no. 19825, fig. 21) from locality 2029 represents a protohippine horse of approximately the stage of evolution seen in one form of *Merychippus* near *calamarius* of the Barstow fauna. The crown is of moderate length and well cemented. The metaconid-metastylid column is short anteroposteriorly.

A fragment of an incisor (no. 22287, fig. 22) shows well-marked cupping and abundant cement in the pit. The stage of evolution of this tooth is approximately that of *M. calamarius*.

PROTOHIPPUS?, sp.

Several fragments of upper cheek-teeth from localities 1979, 1984, 2029, and 2025 represent protohippine forms (fig. 24) at least as large as a very large *Merychippus* or *Protohippus* species of the Barstow fauna. These specimens may represent an advanced *Merychippus*, a *Protohippus*, or possibly a *Hipparion*. A rather narrow fossette of an upper cheek-tooth shows considerable crinkling of the enamel. It may represent a *Merychippus* or a *Hipparion*.

A large incisor (fig. 25) with deep cement-filled pit is larger than the incisors of any protohippine form known from the Barstow fauna. It corresponds more nearly to the stage of advance of a large *Hipparion* form of the Ricardo fauna.

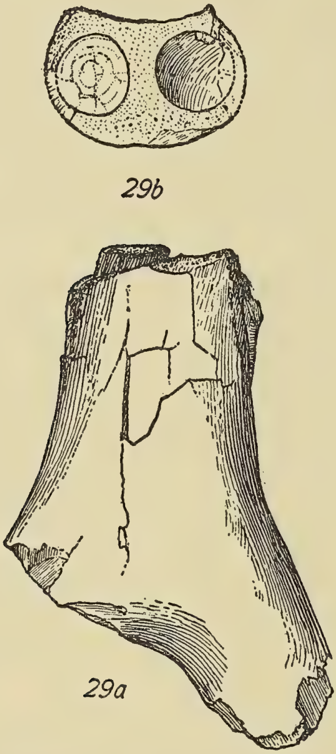
A fragment of a lower cheek-tooth (no. 21483, fig. 23) exceeds the dimensions of the average of the largest protohippine form of the Barstow fauna. The metaconid-metastylid column is short anteroposteriorly, and of the *Pliohippus* rather than of the *Hipparion* type.

The horses of the Cedar Mountain region possibly represent two horizons; one near that of the Barstow beds; the other possibly later and nearer the Ricardo stage, or possibly intermediate between Barstow and Ricardo.

Proboscidea

TETRABELODON, sp.

Remains representing a large mastodon-like form are known from locality 1988. Several fragments of the lower jaw show a dentition including at least three cheek-teeth simultaneously in place in the mandible. Two large lower tusks are in place in the anteroposteriorly elongated symphysial portion of the jaw (figs. 29*a* and 29*b*). A partial enamel covering is shown on the lower tusks. No specimens have been found in which the occlusal portion of the cheek-teeth is satisfactorily shown.



Figs. 29*a* and 29*b*. *Tetrabelodon*, sp. Symphysial region of mandible, inferior view and cross-section, no. 22292, × ¼. Fig. 29*a*, inferior view; fig. 29*b*, cross-section of distal end showing inferior incisors.

Camelidae

PROCAMELUS, near GRACILIS Leidy

A specimen, no. 19820 (figs. 30*a* to 33) representing a small camel found by Baker and Buwalda, at locality 2028 in Stewart Valley, consists of a mandible with dentition, the anterior end of the cranium, a nearly complete anterior limb, six vertebrae and several other scattered fragments of the skeleton.

This species is near *Procamelus gracilis* and *P. occidentalis*, but is nearer the former in absolute size and in proportions of premolars. The dimensions of the Nevada form are close to those of Leidy's type and are near those of the specimen from New Mexico originally described by Cope as *P. occidentalis*,[8] but later referred by him to *P. gracilis*.[9] Cope's specimen is slightly smaller and the metapodials seem a little more slender, but as nearly as can be determined by comparison of the upper jaw in Cope's specimen with the lower jaw from Nevada, the reduction of the premolars is nearly the same.

The reduction of the inferior premolars compared with the size of the molars, and especially with that of M_3, is greater than in any of the other *Procamelus* forms known to the writer.

The Nevada form differs from *P. robustus* Leidy and *P. madisonianus* Douglass through its smaller size; from *P. lacustris* Douglass through its smaller premolars; from *P.? elrodi* through its shorter molar-premolar series, and smaller premolars; from *P. fissidens* Cope through its relatively reduced premolars.

In the cranial fragment represented in specimen no. 19820 (figs. 31*a* to 31*c*), the rostrum is somewhat higher and in superior view apparently wider than in the skull of *P. gracilis* figured by Cope.[10] The Nevada specimen has been crushed slightly and this may account to some extent for its apparently greater relative width. The narrow nasals are in broad contact with the premaxillaries anteriorly. In the Nevada specimen, the palatal surface between the anterior premolars is much narrower relatively than in the specimen described by Cope.

The mandible (figs. 30*a* and 30*b*) does not appear to differ in proportions from that of *P. occidentalis* and *P. robustus*.

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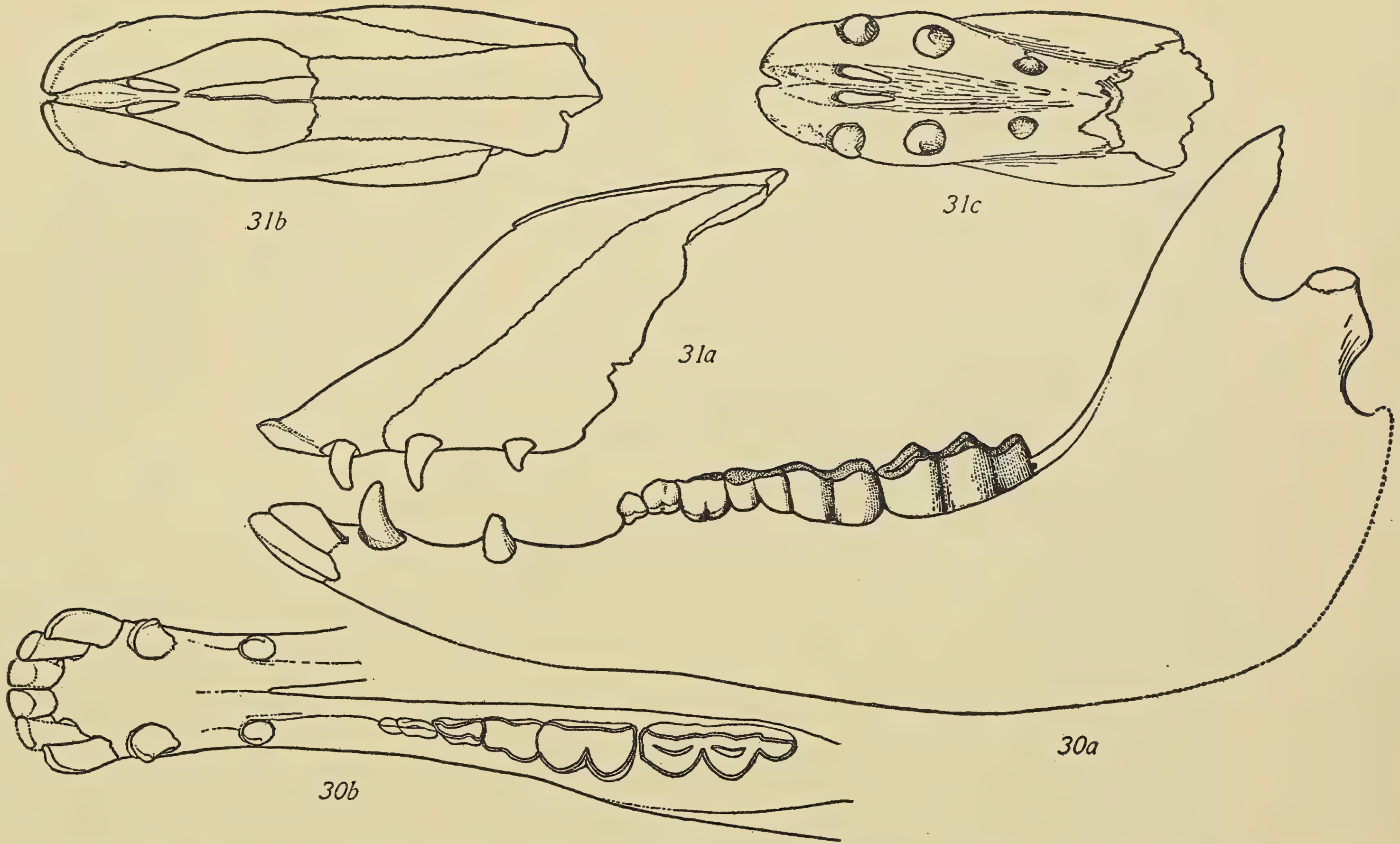
[8] Cope, E. D., U. S. Geol. Surv. west of 100th meridian, vol. 4, p. 329, 1877.

[9] Cope, E. D., Geol. Surv. Texas, 3rd Ann. Rep. for 1891; footnote on p. 37.

[10] *Op. cit.*, pls. 76 and 77.



Figs. 30*a* to 31*c*. *Procamelus*, near *gracilis* Leidy. Mandible with a portion of the rostral region, no. 19820, × ½. Cedar Mountain beds, Stewart Valley, Nevada. Fig. 30*a*, mandible, lateral view; fig. 30*b*, mandible, superior view; fig. 31*a*, rostral region, lateral view, showing premaxillary with a portion of the nasals and maxillary; fig. 31*b*, rostral region, superior view; fig. 31*c*, rostral region, palatal view.

In the inferior dentition every element is represented. The wide crown of I_3 is separated from the canine by a diastema less than one third the length of the diastema between the canine and P_1. P_2 has a simple blade-like crown. The root is grooved laterally and may be completely divided at the lower end. P_3 has a blade-like crown with faint incipient folds of the enamel at the anterior and posterior ends of the inner side. The worn crowns of the fourth premolars show a posteroexternal and an anterointernal fold. The crowns are probably in too advanced a stage of wear to show the posterior fold. M_1 is much worn and shows no distinctive characters. In M_2 the posterior lobe is relatively wide transversely. M_3 is uncommonly long anteroposteriorly. Compared with other forms its anteroposterior diameter is very large in relation to the dimensions of the premolars. The posterior lobe of M_3 stands almost parallel with the plane of the first and second lobes, showing a scarcely perceptible bend outward. The medial wall of the posterior lobe is nearly even with the plane of the middle lobe, but is separated from it by a small, sharply-marked fold or jog of the inner wall.

Excepting I_3, the canine, and P_1 the upper dentition is known only by fragments.

An anterior limb (figs. 32 and 33) lacking only the terminal phalanges and the proximal end of the humerus closely approaches the characters shown in the limb of the specimen of *Procamelus gracilis* described by Cope from New Mexico. The metapodials of the Nevada specimen are about one tenth larger than in the New Mexico form, and also slightly heavier. The two elements of the cannon bone are completely fused, though the distal separation reaches considerably higher on the shaft than in the llama.

The epipodial segment of the limb does not differ noticeably from that of the New Mexico specimen. The ulna and radius are completely fused.

Measurements

	Nevada specimen No. 19820	P. gracilis Cope's New Mexico specimen	P. occidentalis Type specimen	P. robustus Type specimen
Length, anterior side I^3 to posterior side P^1....	54 mm.	44	....	....
Length, posterior side superior canine to anterior side P^1..........................	20.5	16	....	....
Width between inner sides of third upper incisors..................................	22.7	20	....	....
Width between inner sides of first upper premolars................................	12.4	16	....	....

MEASUREMENTS—*Continued*

	Nevada specimen No. 19820	P. gracilis Cope's New Mexico specimen	P. occidentalis Type specimen	P. robustus Type specimen
Length, anterior side inferior canine to posterior side M_3	178 mm.	....	....	....
Length, anterior side P_2 to posterior side P_4	29	....	42.2	48
Length, anterior side P_2 to posterior side M_3	111	....	....	....
Length, anterior side M_1 to posterior side M_3	81.2	....	....	....
Height of mandible below anterior side of M_3	50.7	....	....	60
Height of mandible below anterior side of M_1	47.5	....	....	52.5
Anteroposterior diameter of symphysis	60	....	....	....
		P. gracilis Type specimen		
Inferior canine, greatest anteroposterior diameter	8.2		....	....
P_1, greatest anteroposterior diameter	8.5		....	....
P_2, greatest anteroposterior diameter	8	8	13	15
P_3, greatest anteroposterior diameter	11.9	10.2	14.7	17.3
P_4, greatest anteroposterior diameter	14.8	12.5	16.4	20.3
M_1, greatest anteroposterior diameter	16.6	....	22	29.8
M_2, greatest anteroposterior diameter	25	....	28.5	33?
		P. gracilis Cope's New Mexico specimen		
M_2, greatest transverse diameter of posterior lobe	16.2		....	....
M_3, greatest anteroposterior diameter	40		37	48
Anterior cannon bone, greatest length	245	222	....	....
Anterior cannon bone, greatest proximal width	43	35.3	....	....
Anterior cannon bone, greatest distal width	51.5	42.6	....	....
Anterior cannon bone, least transverse diameter of shaft	23.5	20.4	....	....
Phalanx one, anterior extremity, greatest length	75	65	....	....

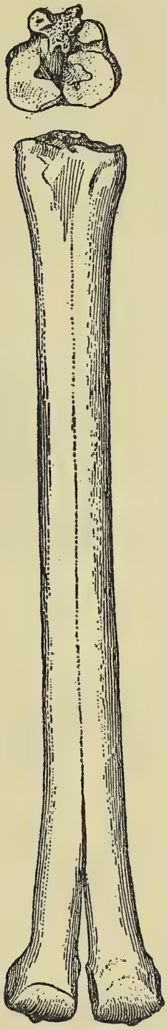
A well-preserved atlas and a portion of an axis with specimen 19820 do not differ appreciably from those of Cope's New Mexico specimen excepting in their slightly larger size.

PLIAUCHENIA?, sp.

Astragali and phalanges (figs. 35, 37 and 40) of a large camel having at least twice the bulk of *Procamelus gracilis* are found in the Cedar Mountain fauna. These elements correspond approximately to foot-bones referred to the genus *Pliauchenia* in the fauna of the Barstow beds. Until material showing structure of dentition and limbs is adequately represented, it is useless to speculate as to the specific determination of the form represented by these specimens.

MERYCODONTIDAE

A small collection of the material including antlers, teeth, and a portion of a jaw from the Cedar Mountain region represents one or



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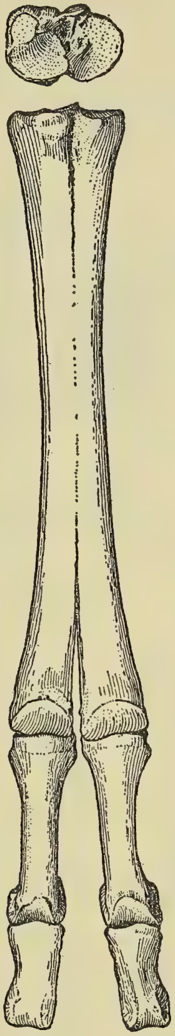

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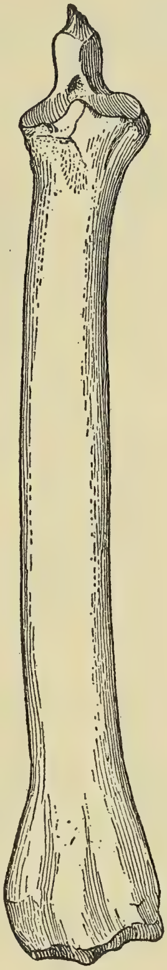

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Figs. 32 to 34. *Procamelus*, near *gracilis* Leidy. Cedar Mountain beds, Nevada.

Fig. 32. Epipodial segment, anterior limb, no. 19820, × ⅓.

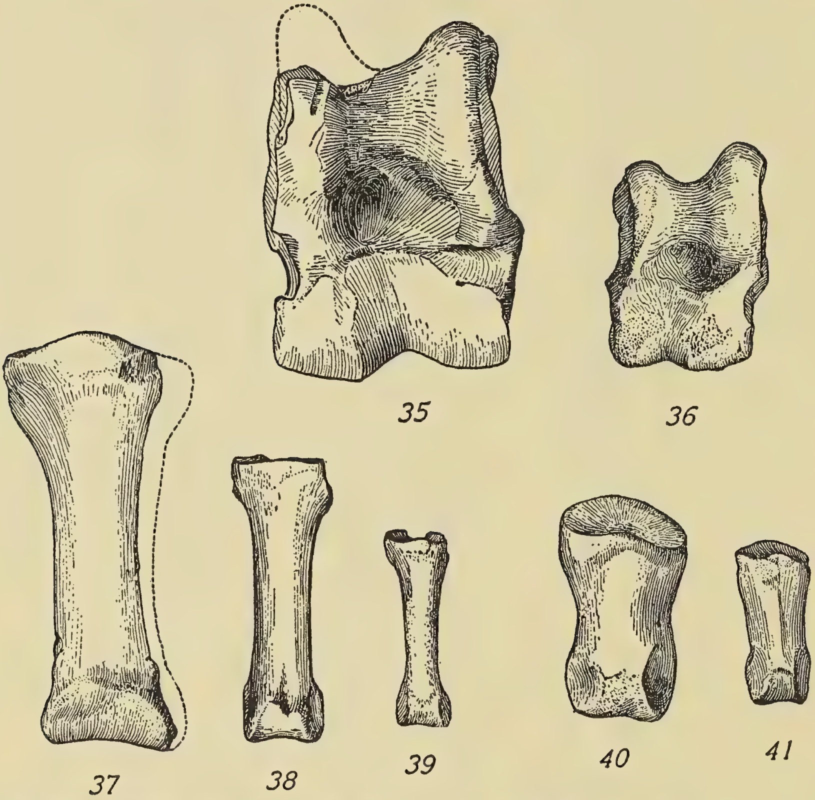
Fig. 33. Metapodials and phalanges, anterior limb, no. 19820, × ⅓.

Fig. 34. Cannon bone, posterior limb, no. 22293, × ⅓.

more species of *Merycodus*. One form seems identical with *M. furcatus*, another is indistinguishable from antlers which form a part of the series included in *M. necatus* from the Barstow beds.

MERYCODUS FURCATUS (Leidy)

A nearly complete antler no. 21492 (fig. 44) from Ione Valley resembles *Merycodus furcatus* in the round, little-flattened beam with strongly-curved, slender tines.



Figs. 35–41 represent specimens from the Cedar Mountain beds in Nevada.

Fig. 35. *Pliauchenia?*, sp. Astragalus, no. 22294, × ½.

Fig. 36. *Procamelus*, sp. Astragalus, no. 22295, × ½.

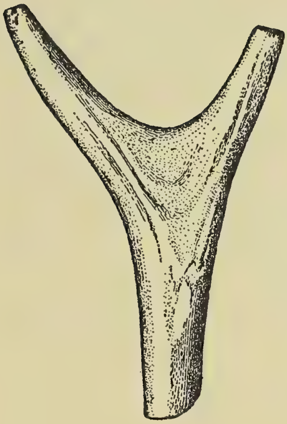
Fig. 37. *Pliauchenia?*, sp. Proximal phalangeal element, no. 22302, superior view, × ½.

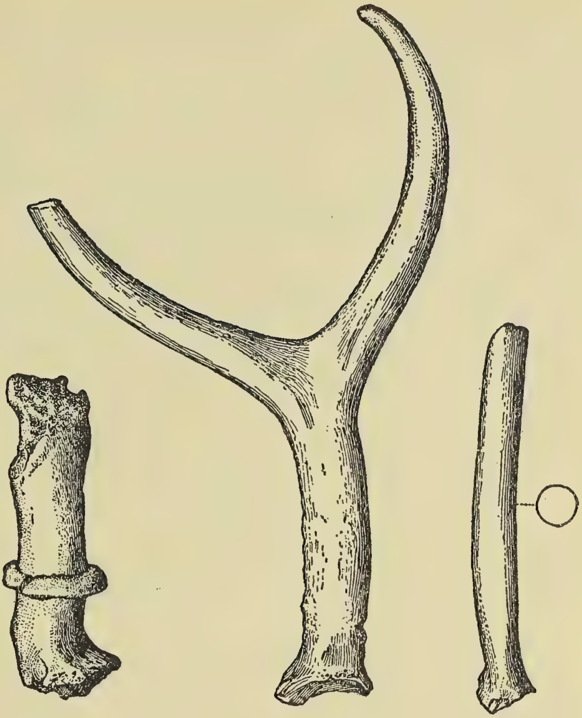
Figs. 38 and 39. *Procamelus*, two species? Proximal phalangeal elements, superior view. Fig. 38, no. 22296, × ½; fig. 39, no. 22297, × ½.

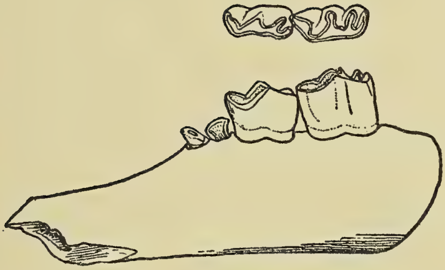
Fig. 40. *Pliauchenia?*, sp. Second phalangeal element, superior view, no. 22298, × ½.

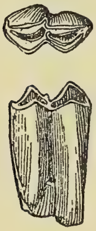
Fig. 41. *Procamelus*, second phalangeal element, no. 22299, × ½.

A second specimen, no. 19807 (fig. 45) shows a long, slender beam with nearly circular cross-section. It is broken above and shows no tines. This form of antler is entirely unlike that of *Merycodus necatus*, but may appear in *M. furcatus*. The majority









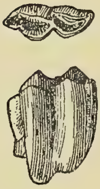


Fig. 42. *Merycodus*, near *necatus* Leidy. Antler, no. 21493, × ½. Cedar Mountain beds, Ione Valley, Nevada.

Figs. 43 to 45. *Merycodus furcatus* (Leidy). Antlers, × ½. Cedar Mountain beds, Nevada. Fig. 43, no. 19806, Ione Valley; fig. 44, no. 21492, Ione Valley; fig. 45, no. 19807, Stewart Valley.

Figs. 46 to 48. *Merycodus*, sp. Cedar Mountain beds, Stewart Valley, Nevada. Fig. 46, lower jaw with P_2 to P_4, no. 19805, × ½; fig. 47, M_2, no. 22300, natural size, external and occlusal views; fig. 48, M_3, no. 22301, external and occlusal views, natural size.

of the fragments of antlers found seem most nearly to approach the *M. furcatus* type.

A portion of a jaw, no. 19805 (fig. 46) found at the same locality with the slender antler no. 19807 shows the last two inferior premolars. A number of scattered teeth include M_2 and M_3. The lower molars are strongly hypsodont. M_3 (fig. 48) shows a moderately developed third or posterior lobe. The premolars in no. 19805 are somewhat elongated, while the inner lateral grooves are short and deep. The outer posterior lateral groove is imperfectly marked, and in this respect these teeth seem less progressive than in the premolars from the Barstow fauna referred to *M. necatus*. According to Cope's figures,[11] *M. furcatus* seems to be distinguished from *M. necatus* by narrower inferior premolars with less marked posteroexternal groove. These teeth are in some respects like those of *Blastomeryx*, but the crowns are more hypsodont. From the character of this specimen and its association with molars and antlers of *Merycodus*, it is probably to be referred to that genus.

MERYCODUS, near NECATUS Leidy

A single antler no. 21493 (fig. 42) from Ione Valley shows a form not distinguishable from one phase of the series of antlers referred to *Merycodus necatus* in the Barstow fauna. The form of the antler is not greatly different from that in no. 21492 (fig. 44) referred to *M. furcatus*, but the beam is more strongly flattened and broadens more gradually above. The tines seem to have been relatively smaller, shorter, and less curved than in the other form. This specimen may represent only a form of the *M. furcatus* series, but must be recognized tentatively as like the form from the Barstow beds referred to *M. necatus*.

A calcaneum from locality 2022 in Ione Valley represents a Merycodus species.

DESCRIPTION OF COLLECTING LOCALITIES IN THE CEDAR MOUNTAIN REGION OF WESTERN NEVADA

Loc. 1969. South side of gulch in low bluffs just west of outcrop of plutonic rock, on south side of road ⅛ mile east of point at which 5,800-foot contour crosses the direct road from Bell Spring to Black Spring. Basal beds. Tonopah Quadrangle.

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[11] Cope, E. D., U. S. Geol. Surv. West of 100th meridian, pl. 82, figs. 1*a* to 2*b*, 1877.

Loc. 1970. Fifty feet stratigraphically above very fossiliferous shell beds on north side of shallow canyon, ½ mile north of the direct road from Bell Spring to Black Spring. Elevation 6050 feet. Tonopah Quadrangle.

Loc. 1971. At 6250 feet elevation, 1 mile north of road intersection which intersection is 2 miles southeast of Bell Spring. Probably near base of lake beds series. Tonopah Quadrangle.

Loc. 1972. At 6075 feet elevation, ½ mile northwest of point at which 6000-foot contour crosses the road between Bell Spring and Black Spring. Tonopah Quadrangle.

Loc. 1973. In first gulch north of direct road from Bell Spring to Black Spring. Between 5900 and 6000-foot contours, on a small hill in the middle of the gulch. Horizon not near base. Tonopah Quadrangle.

Loc. 1974. One-fourth mile northeast of loc. 1973. Tonopah Quadrangle.

Loc. 1975. At 5775-foot elevation, ½ mile north of direct road from Bell Spring to Black Spring. Tonopah Quadrangle.

Loc. 1976. In a fine, light brown tuff 30 or 40 feet above the granite contact, at a point on the 6000-foot contour, about 1½ miles north of the direct road from Bell Spring to Black Spring. Tonopah Quadrangle.

Loc. 1977. On the 6300-foot contour, about ½ mile south of conspicuous, lava covered butte, which is 1½ miles east of Bell Spring. Tonopah Quadrangle.

Loc. 1978. On the southern-most flanks of the Shoshone Mountains, about ½ mile north of the road between Black Spring and Cloverdale and about 300 yards east of the road to Willow Springs near 5500-foot contour. Tonopah Quadrangle.

Loc. 1980. About ½ mile north of loc. 1969, in a small side canyon 50 yards east of low cliffs in the first large canyon north of the direct road from Black Spring to Bell Spring. Tonopah Quadrangle.

Loc. 1982. Near the bottom of gulch ½ mile north of highest butte of the Esmeralda beds in the middle of Stewart Valley, ½ mile west of Finger Rock Wash, and about 2 miles west of Stewart Spring. Soft rusty-brown beds. Tonopah Quadrangle.

Loc. 1984. In Finger Rock Wash at elevation of 5550 feet. Tonopah Quadrangle.

Loc. 1985. About ½ mile due west of loc. 1986, in the strata immediately above the gray tufaceous layer prominently exposed along the west side of the gulch. Tonopah Quadrangle.

Loc. 1986. Immediately south of the point at which the mapped road from Stewart Spring to Pactolus crosses the line between Nye County and Esmeralda County. Tonopah Quadrangle.

Loc. 1987. One-half mile southwest of the point at which 6000-foot contour crosses the line between Nye County and Esmeralda County, about 3 miles north of the Nevada Mine. Tonopah Quadrangle.

Loc. 1988. A point immediately west of the intersection of the 6000-foot contour and the line between Nye County and Esmeralda County, about 3 miles north of the Nevada Mine. Tonopah Quadrangle.

Loc. 1989. Three miles east of Table Mountain, immediately northwest of small hill west of road leading north to Stewart Spring, longitude 117° 55′ west, latitude 38° 32′ north. Tonopah Quadrangle.

Loc. 2021. On 5900-foot contour 2¾ miles due west of B. M. 5571, which B. M. is near Black Spring. Tonopah Quadrangle.

Loc. 2022. One-fourth mile southeast of loc. 2021. Tonopah Quadrangle.

Loc. 2023. One-half mile west of loc. 2021 and in the same gulch on the 6000-foot contour. Tonopah Quadrangle.

Loc. 2024. About ¼ mile due west of loc. 2021 on the south side of the same gulch. Tonopah Quadrangle.

Loc. 2025. About ⅜ mile south of loc. 2021, near the 6000-foot contour. Tonopah Quadrangle.

Loc. 2026. About 2 miles south, 76° west, from the higher of two buttes situated in Stewart Valley, about ½ to ¾ of a mile west of the point where Stewart Spring Gulch joins Finger Rock Wash. About 200 feet above the base of the series. Tonopah Quadrangle.

Loc. 2027. Gray beds in the forks of the mapped roads at Stewart Spring. Tonopah Quadrangle.

Loc. 2028. Along the road one mile west of loc. 1986. Tonopah Quadrangle.

Loc. 2029. One-half mile northeast of loc. 1986 in gulch cut into brown tuff. Tonopah Quadrangle.

Loc. 2030. About 2 miles west of the Nevada Mine and immediately south of the East West road at this point. Tonopah Quadrangle.

Loc. 2031. In limestone about ⅝ mile southwest of the Nevada Mine, on a sharp jagged hill about 200 feet high, just west of the exposure of white igneous rock. Tonopah Quadrangle.

Loc. 2032. About 2½ miles southwest of the Nevada Mine, at an elevation of 6300 feet. Tonopah Quadrangle.

Transmitted August 24, 1914

TAPIR REMAINS FROM LATE CENOZOIC BEDS OF THE PACIFIC COAST REGION

CONTENTS

Introduction....1403
Specimen from Auriferous Gravels of California....1403
Specimen from Marine Beds at Cape Blanco, Oregon....1406
Summary....1408

Introduction

The only certainly known remains of Tapiridae from the Pacific Coast province of North America consist of two specimens. One is a single tooth obtained many years ago from the Auriferous Gravels of California. The other specimen is a portion of an upper jaw with teeth, recently discovered in marine deposits near Cape Blanco, Oregon. As this material is of considerable importance in a study of late Cenozoic history of the Pacific Coast region, it is desirable to place on record such information relating to it as is available.

For the California specimen, which was presented to the University some years ago, the writer is indebted to Dr. Wm. J. Sinclair, through whom it was given to the University by Mr. Benjamin Pownell.

For the privilege of examining and describing the second specimen the writer wishes to acknowledge his indebtedness to Mr. Frank M. Anderson and to Mr. Bruce Martin of the California Academy of Sciences.

Specimen from Auriferous Gravels of California

A lower molar tooth presented by Mr. Benjamin Pownell to the University of California some years ago is the only available specimen representing the Tapiridae in California. This tooth was originally in the collection of Dr. Snell, and as suggested by Dr. Wm. J. Sinclair, who obtained it from Mr. Pownell, it may be the tooth

University of California Publications, Bulletin of the Department of Geology, vol. 7, no. 9, pp. 169–175, January 8, 1913.

to which reference is made by Wm. P. Blake and later by J. D. Whitney. In a note on the occurrence of fossil remains of the tapir in California published in 1868, Blake[1] stated that remains of this animal had been found at a depth of forty feet below the surface in the auriferous gravels at Wood's Creek near Sonora, Tuolumne County, California. The specimens were said to have been presented to Blake by Dr. Snell of Sonora. The material consisted of a lower molar and possibly an epiphysis of a cervical vertebra. The tooth was determined by Professor Owen of the British Museum as the "crown of the left lower molar tooth of a tapir." The specimen mentioned by W. P. Blake is referred to by J. D. Whitney[2] in 1879 in his discussion of the Auriferous Gravels.

The tooth presented to the University by Mr. Pownell is a left lower molar. It is apparently M_2. It seems to be distinguished from M_3 mainly by the relatively greater width of the posterior half of the tooth. The anterior and posterior transverse ridges are unworn and show only faint indications of notches between protoconid and metaconid, and between hypoconid and entoconid. There is an anterior and a posterior cingulum. The posterior cingulum is narrow transversely. On the anterior side of the crown there are two basal ridges. One is median and is partly confluent with the anterior ridge of the protoconid. The other anterior basal ridge lies below and in front of the one just described, and forms a distinct shelf on the external side of the anterior end of the tooth. It reaches nearly to the extreme outer border of the tooth. On both the outer and inner sides of the tooth small tubercles are developed between the bases of the anterior and posterior transverse ridges. The inner tubercle is very faint, but the outer one is a noticeable feature of the tooth (see figs. 1*a* to 1*c*).

The specimen just described does not differ greatly from M_2 and M_3 of *Elasmognathus bairdii*. It is distinguished by the slightly larger anteroposterior diameter of the anterior basal ridges, and by the smaller size of the external basal tubercle between the metalophid and hypolophid. In the only specimen of *E. bairdii* available for comparison the posterior molars are somewhat worn and the characters of the transverse ridges are not as clearly shown as in the fossil specimen.

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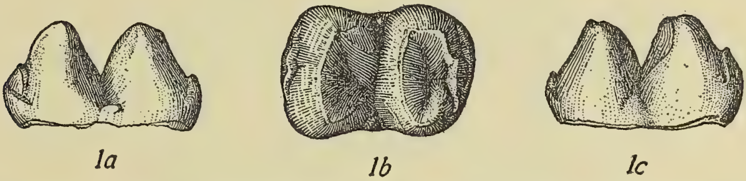
[1] Blake, Wm. P., Amer. Jour. Sc., ser. 2, vol. 45, p. 381, 1868.

[2] Whitney, J. D., Mus. Comp. Zool., vol. 6, p. 250, 1879.

In such figures of the dentition of *Tapirus terrestris* as are available, the characters of M_3 seem very close to those of the fossil from California, though the details of form are not clearly discernible on any figures of *T. terrestris* at hand.

The type specimen of *Tapirus haysii* figured by Leidy[3] seems to show anterior and posterior cingula, and an external basal tubercle between the metalophid and hypolophid. The width or transverse diameter of the tooth is, however, relatively much greater compared with the length or anteroposterior diameter, the relation being as 22.3:27 in *T. haysii*, and 17.8:25.3 in the California specimen. As the teeth compared are both presumed to represent M_2 of the left side, it would seem that the considerable variation in width, amounting to at least twelve per cent, may represent specific or subspecific difference. In *Elasmognathus bairdii* the ratio of width to length is intermediate between that in the California specimen and that in the type of *T. haysii*.



FIGS. 1*a* TO 1*c*. *Tapirus haysii californicus*, n. subsp. M_2(?). No. 8747, natural size. From the Auriferous Gravels of California. Fig. 1*a*, outer view; fig. 1*b*, superior view; fig. 1*c*, inner view.

The tooth from California represents a form approaching *Elasmognathus bairdii* of the Recent fauna in certain characters. In some respects it is intermediate between *E. bairdii* and *Tapirus terrestris*. Though the California specimen shows some resemblance to *T. haysii*, the considerable difference in form of M_2 makes it very difficult to believe that the two are specifically identical. The specimen seems at least as near *E. bairdii* as to any described species, but the nature of the cingula and of the tubercles between metalophid and hypolophid seem to distinguish it from that form. The writer considers that a tentative recognition of the distinguishing characters of the California specimen, together with an indication of its geographic location, is more desirable than a very doubtful

[3] Leidy, J., in Holmes Post-Pleiocene Fossils of South Carolina, pl. 17, figs. 7 and 8, 1860.

reference to one of the described species. This form is therefore tentatively distinguished as *Tapirus haysii californicus*.

Measurements

	No. 8747[4]	E. bairdii	T. haysii
M_2, anteroposterior diameter	25.3 mm.	22	27
M_2, greatest transverse diameter	17.8	17.8	22.3

Specimen from Marine Beds at Cape Blanco, Oregon

The tapir specimen from Cape Blanco, Oregon, was obtained in June, 1911, by Mr. Bruce Martin while collecting in the marine beds of that region for the California Academy of Sciences. It was found in the bluff about three miles south of Cape Blanco and one-half mile north of the mouth of Elk River. At this locality the formations comprise two lithologic phases: (1) an upper, gray-buff sand, which is loosely cemented and breaks down readily; (2) a lower, blue-gray, argillaceous sandstone, which is better cemented and forms steeper cliff walls than the upper zone. There is no evident discordance between the upper and lower zones.

A considerable marine fauna obtained from the upper sand by Martin seems quite certainly to represent a phase of the Pleistocene near that of the San Pedro stages. The marine fauna of the lower sand is distinctly older than that in the upper zone, and shows some resemblance to that of the upper Merced series. The lower fauna is not yet well enough known to permit definite reference to a stage of the standard time scale, but seems to be not older than late Pliocene or younger than the earlier portion of the Pleistocene.

The section from which the tapir tooth was obtained has been described by Diller,[5] who refers to an upper horizon as the Elk River Beds. A collection of marine shells from these beds examined by Dall was referred to as "probably Pleistocene, all the species seeming recent, but they may be of the Merced horizon. . . . They are not older than the newer Pliocene." The lower zone at Elk River as described to the writer by Martin is possibly referred by Diller to the Cape Blanco Beds, the equivalent of the Empire Beds. The fauna from the exposures of the Blanco is considered by Diller as Miocene. Mr. Martin believes that the lower horizon of blue-gray argillaceous sandstone is later than the Empire formation which occurs lower down in the section in the cliff farther north. According to Martin the fauna of this blue-gray argillaceous sandstone is much more recent in character than that of the Empire Beds farther north. The tapir specimen is reported from the lower beds.

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[4] From the Auriferous Gravels of California.

[5] Diller, J. S., U. S. Geol. Surv. Bull. 196, p. 30, 1902.

The tapir specimen obtained at Cape Blanco consists of a portion of a maxillary bone with the three molar teeth well preserved and but little worn (fig. 2).

In the portion of the maxillary present there is nothing to distinguish the Cape Blanco form from *Elasmognathus bairdii.*

The molars do not agree exactly in all characters with those of any species available for comparison. From *Tapirus terrestris* they differ considerably in the much smaller parastyle of M^2. From *T. roulini* they are distinguished by the relatively smaller size and more nearly quadrate form of M^2. From *T. indicus,* they are separated by the more nearly square cross-section of M^2, and by the tendency to development of an external cingulum on the outer side of the metacone pillar of M^2. The Cape Blanco form approaches *Elasmognathus bairdii* in the nearly quadrate form of M^2, and in the presence of a weak cingulum on the outer side of the metacone pillar of M^2. There is also a faint suggestion of a tubercle on the inner side of M^1 between the protocone and hypocone pillars as in *E. bairdii.* It seems possible to distinguish the Cape Blanco form from *E. bairdii* by the weaker external cingulum on the outer side of M^2, by the absence of a cingulum on the corresponding region of M^3, and by the absence or imperfect development of the tubercle on

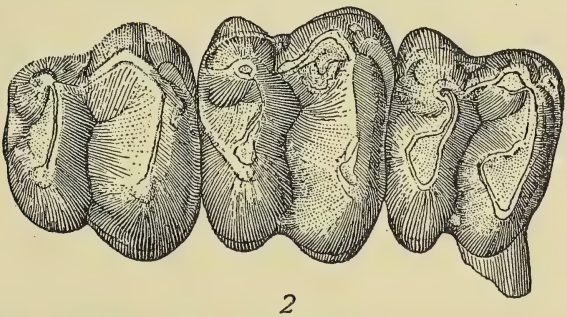

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FIG. 2. *Tapirus,* near *haysii californicus,* n. subsp. Superior molar series, natural size. From early Pleistocene or late Pliocene marine deposits three miles south of Cape Blanco, Oregon.

the inner wall of the molars between protocone and hypocone. There is also a less distinctly noticeable evenness of the molars in form and size in the Cape Blanco form than in the Recent *E. bairdii.*

With *Tapirus haysii* Leidy from the Pleistocene of southern and eastern United States it is not possible to make an entirely satisfactory comparison, as no good figures are available. The specimen figured by Leidy[6] from the Brasos River near San Fillipe, Texas, is somewhat worn and the diagnostic characters are not clearly shown. The dimensions are very near those of the Cape Blanco specimen. This specimen is evidently near *Tapirus haysii*, and may be referred to tentatively as *Tapirus*, near *haysii californicus.*

MEASUREMENTS

	Cape Blanco specimen	E. bairdii	T. haysii
M^1, anteroposterior diameter	21.5 mm.	19.5	21.5
M^1, greatest transverse diameter	27.3	24	27.5
M^2, anteroposterior diameter	24.8	22.5	25.5
M^2, greatest transverse diameter	30.5	25.9	32
M^3, anteroposterior diameter	25.7	21.8	
M^3, greatest transverse diameter	30	25.5	

SUMMARY

The tapir specimens from the Auriferous Gravels of California and from the marine beds of Cape Blanco, Oregon, both represent species not distantly removed from the existing *Tapirus* (*Elasmognathus*) *bairdii.*

The California specimen seems to be near *Tapirus haysii*, but shows differences which appear to be of at least subspecific value. This form is tentatively referred to as *Tapirus haysii californicus*, n. subsp.

The Cape Blanco specimen is near *Tapirus haysii*, and shows indication of relationship to *Elasmognathus bairdii.* It is probably near the form from the Auriferous Gravels, and is referred to as *Tapirus*, near *haysii californicus.*

The Auriferous Gravel and Cape Blanco specimens both seem to represent a stage of evolution quite certainly not earlier than late Pliocene, and probably not older than early Pleistocene.

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[6] Leidy, J., in Holmes, Post-Pleiocene Fossils of South Carolina, pl. 17, fig. 1, 1860.

NOTES ON THE CANID GENUS TEPHROCYON

The genus *Tephrocyon* includes a group of American canids with characters in some respects foreshadowing *Aelurodon*, and in other points resembling *Canis*. These forms range from the middle Miocene to early Pliocene, and are found distributed over the western portion of the continent.

The material representing the described forms is mostly fragmentary and imperfectly known, and the species were in a considerable part originally referred to *Canis* in the absence of clearly distinguishing characters. Since the description of the generic type of *Tephrocyon*, based upon a good skull and dentition from the Middle Miocene of Oregon, it has been noted that a number of the species from the West-American Miocene which were previously referred to *Canis* find a place in this genus; and it is probable that still other species of uncertain position belong here. On the other hand, it is probable that some of the species based on fragmentary material and referred to *Tephrocyon* do not represent that genus.

The following notes are presented with a view to bringing together such information as is available relating to this group, in the hope that this statement may serve to stimulate further assembling of information, and more careful revision of the forms related to *Tephrocyon*.

In preparing the following paper the writer has made a reexamination of the type specimen of *Tephrocyon*, and several figures representing phases of the structure not previously illustrated accompany this discussion.

For the loan of the type specimen from the University of Oregon, the writer is much indebted to Professor A. J. Collier and Professor J. F. Bovard.

GENUS TEPHROCYON

Type species *Tephrocyon rurestris* (Condon).

Skull of the type specimen short-muzzled, shortening of the muzzle accompanied by backward extension of the premaxillaries

University of California Publications, Bulletin of the Department of Geology, vol. 7, no. 18, pp. 359–372, September 23, 1913.

beyond the anterior ends of the nasal processes of the frontals, auditory bullae large. Paroccipital process prominent. Mandible heavy, uncommonly convex below the anterior border of the masseteric fossa. Crushing region of the molar teeth relatively large. M^1 and M^2 with inner lobe relatively wide anteroposteriorly. M_1 with well-developed metaconid and large heel. M_2 relatively long anteroposteriorly, paraconid ridge or tubercle distinct, antero-external ridge of the cingulum strongly marked. Premolars usually relatively short. P^4 with an incipient protostyle in the type specimen of the genus. Posterior opening of the vertebrarterial canal of the atlas situated farther back than in *Canis*.

The forms that have been referred to *Tephrocyon* include the following:

T. rurestris (Condon). Mascall Beds, Oregon. Middle Miocene.

T. hippophagus Matthew and Cook. Snake Creek, Nebraska. Early Pliocene.

T. temerarius (Leidy). Sands of the Niobrara River, Snake Creek?, and Whistle Creek, Nebraska; Mohave Beds, Mohave Desert, California. Upper Miocene.

T. kelloggi Merriam. Virgin Valley Beds, Nevada, Middle Miocene; Cedar Mountain, Nevada, Middle to Upper Miocene.

T., near *kelloggi* Merriam. Thousand Creek Beds, Nevada. Early Pliocene.

Tephrocyon, sp. (Matthew and Cook). Snake Creek, Nebraska. Early Pliocene.

Tephrocyon?, sp. (Merriam). High Rock Canyon, Nevada. Middle Miocene.

T. vafer (Leidy)?. Snake Creek, Nebraska. Early Pliocene.

So far as known, the several species may be characterized as follows:

T. rurestris. Mandible short and massive, relatively convex below anterior end of the masseteric fossa. Inferior premolar series short, inferior premolars without anterior cusps, metaconid of M_1 moderately developed, M_2 relatively shorter anteroposteriorly than in *T. kelloggi*, but longer than in *T. hippophagus* and *T. temerarius*.

T. hippophagus. Characters in general much as in *T. rurestris*. Inferior premolar series somewhat longer than in *T. rurestris*. Inferior premolars larger and thicker than in *T. rurestris*, and with anterior cusps on P_2, P_3, and P_4. M_2 slightly shorter and relatively thicker transversely than in *T. rurestris.*

T. kelloggi. Mandible more slender than in *T. rurestris* and *T. hippophagus.* Inferior premolar series relatively long. Inferior premolars small, relatively simple, and without anterior cusps. Metaconid of M_1 relatively large. M_2 relatively long anteroposteriorly.

T. temerarius. Mandible more slender than in *T. rurestris* and *T. hippophagus.* Mandible of Mohave Desert specimen lighter than in *T. kelloggi*; other referred specimens not heavier than *T. kelloggi.* P_4 with anterior cusp or tubercle, other premolars imperfectly known. Metaconid of M_1 of medium size. M_2 relatively much shorter than *T. kelloggi*, and slightly shorter than in the other two species.

COMPARATIVE MEASUREMENTS

	T. rurestris Type specimen	T. hippophagus Type specimen	T. kelloggi Type specimen	T. temerarius No. 19402 Mohave
Length of mandible from anterior side of P_1 to posterior side of condyle	*a*112 mm.	107.	103.7	....
Height of mandible below protocone of M_1	20.	22.5	21.	16.
Greatest thickness of mandible below talonid of M_2	.....	10.	9.	8.4
P_2, anteroposterior diameter	7.5	8.	6.	....
P_3, anteroposterior diameter	9.	9.3	6.7	7.
P_4, anteroposterior diameter	11.5	12.	8.4	8.5
M_1, anteroposterior diameter	20.	19.8	15.	17.
M_1, transverse diameter of heel	*a*8.7	8.3	7.	6.5
M_2, anteroposterior diameter	11.5	10.1	10.5	9.
M_2, greatest transverse diameter	6.8	6.9	6.7	5.7
Length, posterior side inferior canine to posterior side M_2	63 *a*	65.5*a*	61.	....
Length, posterior side inferior canine to posterior side P_4	33 *a*	35.5	36.	....

a, approximate.

TEPHROCYON RURESTRIS (Condon)

Canis rurestris Condon. The Two Islands, p. 139, pl. 18, 1902.
Tephrocyon rurestris. Merriam, J. C., Univ. Calif. Publ., Bull. Dept. Geol., vol. 5, p. 6, 1906.

The type specimen was originally no. 382 in the private collection of Professor Thomas Condon. It is now in the collections of the University of Oregon. The fragmentary specimen consisting of four upper cheek-teeth shown in the lower right hand corner of Condon's figure of *Canis rurestris* (Two Islands, pl. 18) does not pertain to the type of *Tephrocyon rurestris*. These detached teeth represent a species of *Temnocyon*, near *T. altigenis* Cope from the John Day Series.

The type specimen, consisting of a good skull with the atlas and a portion of a tibia, was obtained in the Mascall Beds near Cottonwood, Grant County, Oregon. As nearly as could be determined in conversation with Professor Condon, this specimen was found at the type locality of the Mascall Beds. This horizon is of Middle Miocene age. Other fragmentary material from the Mascall may represent this species.

The skull and dentition of *Tephrocyon rurestris* represents a rather short-headed, heavy-jawed dog with an unusually large crushing area on the molars.

The accompanying figures present the principal characters of this species. (See figs. 1 to 5.)

TEPHROCYON HIPPOPHAGUS Matthew and Cook

Tephrocyon hippophagus Matthew and Cook. Bull. Am. Mus. Nat. Hist., vol. 26, p. 374, 1909.

To this species Matthew and Cook referred eight lower jaws, and a portion of an upper jaw from Snake Creek. The Snake Creek Beds are considered by Matthew and Cook as representing an early phase of the Pliocene.

After an examination of the type specimen of *T. hippophagus*, and a comparison with the type of *T. rurestris* of an excellent cast, kindly furnished by Dr. Matthew, there seems no doubt that this is a form closely related to *Tephrocyon rurestris* and yet is specifically distinct from it.

TEPHROCYON TEMERARIUS (Leidy)

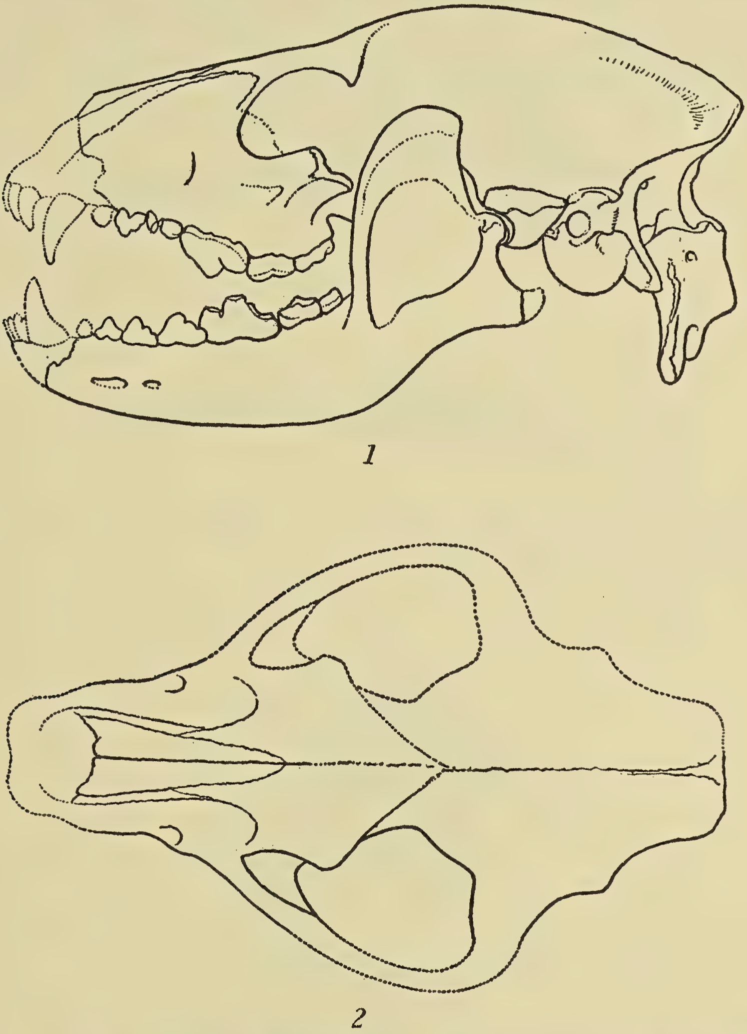
Canis temerarius Leidy. Proc. Acad. Nat. Sc. Philad., p. 21, 1858.

Canis temerarius Leidy. Jour Acad. Nat. Sc. Philad., vol. 7, p. 29, pl. 1, fig. 12, 1869.

? *Tephrocyon* cf. *temerarius*. Matthew and Cook, Bull. Am. Mus. Nat. Hist., vol. 26, p. 376, 1909.

Tephrocyon temerarius. Peterson, O. A., Mem. Carneg. Mus., vol. 4, p. 268, 1910.

The typical material of this species consisted of a piece of a lower jaw containing the carnassial tooth, and a portion of an upper jaw with two teeth both badly preserved. This material was obtained by Dr. Hayden from the Niobrara Sands. The horizon is presumably Upper Miocene. The lower jaw and M_1 figured by Leidy[1] show form and dimensions closely similar to those



Figs. 1 and 2. *Tephrocyon rurestris* (Condon). Type specimen, × ½. Mascall Beds, John Day Valley, Oregon. Fig. 1, lateral view of skull; fig. 2, superior view of skull.

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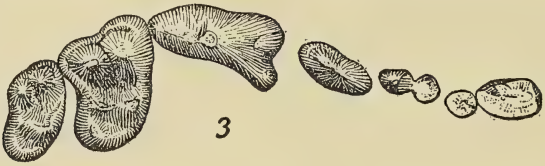
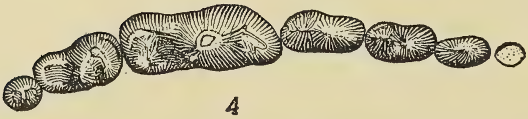
[1] Leidy, J., Jour. Acad. Nat. Sc. Philad., vol. 7, second series, pl. 1, fig. 12, 1869.

of a specimen obtained by Peterson[2] from beds at Whistle Creek, Nebraska, possibly belonging to late Miocene or Pliocene deposits.

A portion of a lower jaw (no. 19402), with P_3 to M_2 inclusive, from the Mohave Beds of the Mohave region, California, very closely resembles the type of Leidy's *Canis temerarius* from the Nebraska formation and also resembles the specimen from Whistle Creek, Nebraska, referred to this species by Peterson. M_1 of the Mohave specimen very nearly approaches in form and dimensions the original figured specimen of *Canis temerarius* (Leidy), and the Mohave species is almost identical in form and dimensions with the corresponding parts of the specimen described by Peterson.





Figs. 3 and 4. *Tephrocyon rurestris* (Condon). Dentition of type specimen, natural size. Mascall Beds, John Day Valley, Oregon. Fig. 3, superior dentition, occlusal view; fig. 4, inferior dentition, occlusal view.

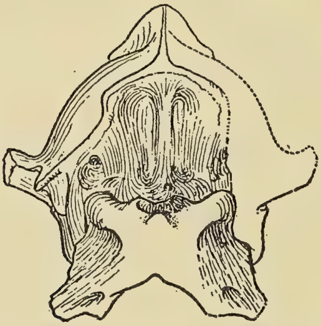


Fig. 5. *Tephrocyon rurestris* (Condon). Type specimen. Posterior view of skull with atlas, × ½. Mascall Beds, John Day Valley, Oregon.

The specimen from Mohave Beds (figs. 8*a* and 8*b*) represents a species of *Tephrocyon* differing slightly from those thus far known in the Great Basin region. The relationship of this form to the genus *Tephrocyon* is shown in the large size of the metaconid and of the crushing heel of M_1, and in the presence of a well-developed paraconid with a large antero-external shelf on the cingulum of M_2.

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[2] Peterson, O. A., Mem. Carneg. Mus., vol. 4, p. 268, 1910.

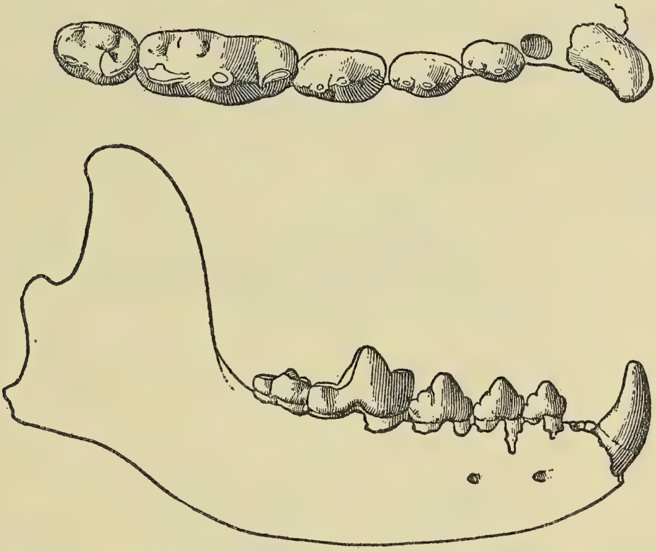


FIG. 6. *Tephrocyon hippophagus* Matthew and Cook. Lower jaw of type specimen, external view, $\times \frac{2}{3}$; and occlusal view of teeth natural size. Am. Mus. N. H., no. 13836. (After Matthew and Cook.)

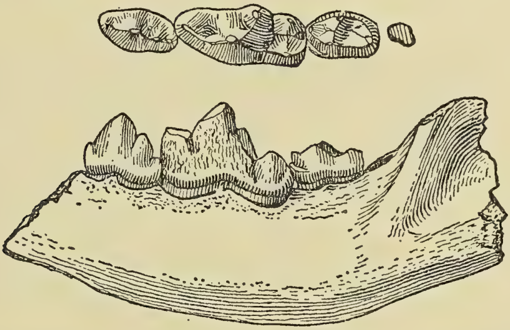
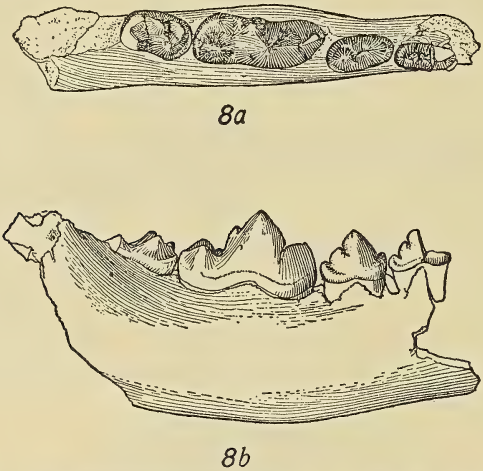


FIG. 7. *Tephrocyon temerarius* (Leidy). Occlusal view of teeth and external view of lower jaw, natural size. (Carneg. Mus. Cat. Vert. Foss. no. 2404.) (After Peterson.)

The Mohave form is distinguished from *Tephrocyon rurestris* and *T. hippophagus* by the smaller, more slender teeth. From *T. kelloggi* it differs in the relatively larger M_1 and smaller M_2, and smaller metaconid of M_1. M_1 in the Mohave specimen measures 17 mm. in anteroposterior diameter as compared with 9 mm. in anteroposterior diameter in M_2. In *T. kelloggi* the anteroposterior diameter of M_1 is 15 mm.; of M_2, 10.5 mm. There is a small hypoconulid on the heel of M_1 in the Mohave specimen, while in the type of *T. kelloggi* this tubercle is not suggested. The heel of M_2 seems somewhat shorter than in *T. kelloggi*.

P_4 and P_3 both possess a posterior cusp and a posterior basal tubercle. P_4 shows a small anterior basal tubercle. The anterior side of P_3 is not preserved.



FIGS. 8*a* AND 8*b*. *Tephrocyon temerarius* (Leidy). A portion of the mandible with dentition. No. 19402, natural size. Mohave Beds, Mohave Desert, California. Fig. 8*a*, superior view; fig. 8*b*, lateral view.

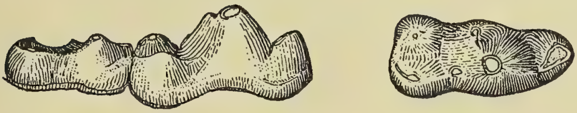
Several specimens of mandibles slightly larger than no. 19402 represent a *Tephrocyon* species from the Mohave Beds very near *T. temerarius*. It is possible that they belong to another species, but age and sex are presumably competent to account for the differences.

TEPHROCYON KELLOGGI Merriam, J. C.

Tephrocyon kelloggi Merriam. Univ. Calif. Publ., Bull. Dept. Geol., vol. 6, p. 235, 1911.

To this species there have been referred several jaws and detached teeth from the middle Miocene Virgin Valley Beds of northern Nevada. A single tooth from the early Pliocene of Thousand Creek, Nevada, closely approaches this species, and a lower carnassial from Cedar Mountain in Middle Nevada represents a closely allied form.

This species differs farther from all of the other three species than any one of these three differs from the others and further study may suggest subgeneric separation. The mandible is more slender than in *T. rurestris* or in *T. hippophagus;* the premolars are relatively smaller, more simple, and more widely spaced than in the other forms; M_2 and the heel of M_1 are relatively long; and the metaconid of M_1 is unusually large and high. The characters of the jaw and dentition are in general those of *Tephrocyon*, and the species is evidently nearer the group of three including *T. rurestris*, *T. temerarius*, and *T. hippophagus* than to any other known dogs.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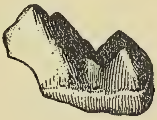
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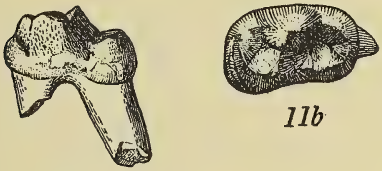
FIGS. 9*a* AND 9*b*. *Tephrocyon kelloggi* Merriam. Type specimen, × 1½. No. 11562. Virgin Valley Beds, Virgin Valley, Nevada. Fig. 9*a*, M_1 and M_2 lateral view; fig. 9*b*, M_1 superior view.

FIG. 10. *Tephrocyon*, near *kelloggi* Merriam. M_1, no. 19767, × 1½. Stewart Valley Beds, Nevada.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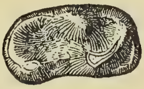
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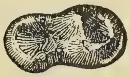
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FIGS. 11*a* AND 11*b*. *Tephrocyon kelloggi* Merriam. M_2, unworn tooth, no. 10651, × 1½. Virgin Valley Beds, Virgin Valley, Nevada. Fig. 11*a*, outer side; fig. 11*b*, superior side.

FIG. 12. *Tephrocyon kelloggi* Merriam. M_2, worn tooth, no. 11474, × 1½. Virgin Valley Beds, Virgin Valley, Nevada.

FIG. 13. *Tephrocyon*, near *kelloggi* Merriam. M_2, no. 12542, × 1½. Thousand Creek Beds, Thousand Creek, Nevada.

The specimen from the Cedar Mountain region of middle Nevada referred to above consists of the greater portion of a single lower carnassial (see fig. 10) from Stewart Valley (locality 2027). It is almost identical in form with M_1 of the type specimen of *Tephrocyon kelloggi* from Virgin Valley, Nevada. The very slight differences between these two specimens are due in a large part to the fact that the Stewart Valley specimen is unworn, while the type has been subjected to moderate wear.

In addition to showing closely similar dimensions, the Stewart Valley specimen resembles M_1 of the type of *T. kelloggi* in the very long heel, and the very large metaconid. There is also close correspondence in a number of minor details, as in the position and form of the small inner and outer tubercles intermediate between trigonid and talonid, the presence of a faint ridge of the cingulum on the outer side of the heel, and the development of a faint ridge on the outer portion of the posterior end of the heel.

COMPARATIVE MEASUREMENTS

	No. 19767	T. kelloggi
M_1, anteroposterior diameter of heel on inner side	4.3 mm.	4.1
M_1, greatest transverse diameter of heel	6.5	7.

SPECIES OF UNCERTAIN RELATIONSHIPS

Several fragmentary specimens representing forms in or near *Tephrocyon* have been described in recent palaeontologic papers. The exact position of the forms represented by this material can not be satisfactorily determined until better specimens are obtained.

A jaw fragment with M_1 and P_4 (no. 13843) obtained by Matthew and Cook[3] at Snake Creek, Nebraska, is doubtfully referred to *Tephrocyon*. It represents a form one half larger than *T. hippophagus*. The heel of M_1 in this form seems shorter than in any other specimen referred to *Tephrocyon*.

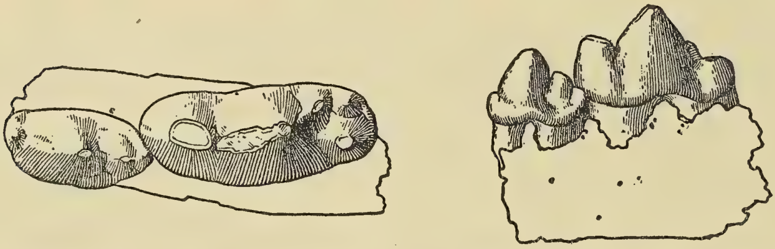

FIG. 14. *Tephrocyon?*, sp. Part of lower jaw with P_4 and M_1. External view × $\frac{2}{3}$, occlusal view of teeth natural size. (Amer. Mus. Nat. Hist., no. 13843.) (After Matthew and Cook.)

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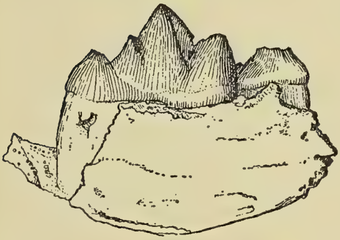
[3] Matthew, W. D., and Cook, H. J., Bull. Am. Mus. Nat. Hist., vol. 26, p. 376, 1909.

A jaw fragment with M_1 and P_4 (no. 12503) from the Middle Miocene of Little High Rock Canyon, Humboldt County, Nevada, is compared with *Tephrocyon rurestris* by Merriam.[4] The general form and measurements are near those of the type specimen of *T. rurestris*. The metaconid of M_1 seems relatively a little smaller and the protoconid and paraconid more acute. This difference, especially as represented in the figure, is largely due to difference in wear. It will be necessary to have more material, and especially to secure a specimen with M_2, before the exact relationship of this form can be determined.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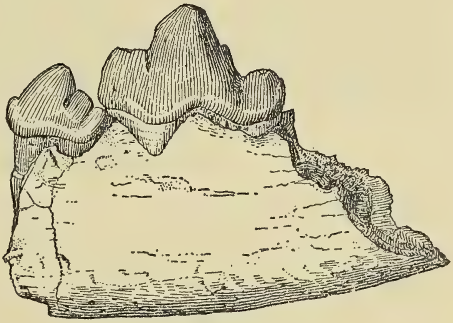
16a

15b

16b

FIGS. 15*a* AND 15*b*. *Tephrocyon?*, compare *rurestris* (Condon). No. 12503, natural size. Virgin Valley Beds, Little High Rock Canyon, Humboldt County, Nevada. Fig. 15*a*, M_1 and P_4 inner view; fig. 15*b*, M_1 occlusal view.

FIGS. 16*a* AND 16*b*. *Tephrocyon?*, sp. No. 12504, natural size. Virgin Valley Beds, High Rock Canyon, Humboldt County, Nevada. Fig. 16*a*, outer side; fig. 16*b*, occlusal view.

A portion of a mandible with M_1 and P_4 (12504) from the Middle Miocene of High Rock Canyon, Humboldt County, Nevada, represents a species larger than that from Little High Rock Canyon. P_4 differs from that of *Tephrocyon rurestris* in the possession of an anterior cusp. The entoconid of the heel of M_1 is relatively smaller than in the specimen from Little High Rock Canyon. In several characters this specimen resembles *T. hippophagus* more nearly than it does *T. rurestris*, but it is probably distinct from both species.

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[4] Merriam, J. C., Univ. Calif. Publ. Bull. Dept. Geol., vol. 6, p. 239 and 240, text-figs. 8*a* and 8*b*, 1911.

Although the specimens from the High Rock and Little High Rock beds resemble the typical *Tephrocyon*, in many respects they are quite different from *T. kelloggi*, and future study of this group of canids may show that the fragmentary forms last described are separable at least by subgeneric characters from the *T. kelloggi* type.

Matthew and Cook[5] have compared fragmentary material from the Snake Creek Beds to *Canis vafer* Leidy, and have tentatively referred this form to *Tephrocyon*. It seems to the writer doubtful whether *Canis vafer* can be included in the same generic group with *Tephrocyon rurestris* and *T. hippophagus*.

RELATIONSHIPS OF TEPHROCYON

Writers[6] who have expressed an opinion on the affinities of *Tephrocyon* have considered this group as distinguished by characters in some respects like those of *Canis*, and in some particulars like those of *Aelurodon*. The further study of the group bears out these assumptions, and future work may show that both *Canis* and *Aelurodon* are derivatives of the *Tephrocyon* type. Later study will probably reveal many varieties of the *Tephrocyon* group as yet unknown, some of which will be more like *Aelurodon* than the species now available. Some of the fragmentary specimens to which reference has been made above show characters verging close to *Canis*.

Bear-like characters, such as are seen especially in M_1 and M_2 of *Tephrocyon kelloggi*, are not considered as indicating that this group is ancestral to any division of the Ursidae. *T. kelloggi* may, however, lead to a very specialized side branch of the Canidae.

Transmitted June 28, 1913

[5] Matthew, W. D., and Cook, H. J., Bull. Am. Mus. Nat. Hist., vol. 26, p. 376, 1909.

[6] Merriam, J. C., *op. cit.*, 1906.
Matthew, W. D., and Cook, H. J., *op. cit.*, 1909.

VERTEBRATE FAUNA OF THE ORINDAN AND SIESTAN BEDS IN MIDDLE CALIFORNIA

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INTRODUCTION

The Orindan and Siestan formations occurring in the hills immediately to the east of Berkeley form the larger part of a thick accumulation of fresh-water and alluvial beds resting uncomformably upon the marine Miocene. The Orindan formation is the lower portion of these beds, and comprises a great thickness of clays, shales, sands, conglomerates, and tuffs, with occasional beds of limestone. The Orindan is followed by a series of igneous rocks consisting mainly of andesite and basalt. The Siestan rests upon the lavas covering the Orindan, and is in turn covered by a volcanic series made up largely of basalt.

The section, from the base of the Orindan to the top of the lavas above the Siestan, contains no marine fossils. It shows scattered through it a few remains of fresh-water Mollusca and Crustacea, land Mollusca, land plants, and land or fresh-water vertebrates. The accumulation as a whole is evidently the result

University of California Publications, Bulletin of the Department of Geology, vol. 7, no. 19, pp. 373–385, September 24, 1913.

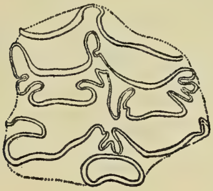
of deposition in a basin which was at times occupied, at least in part, by fresh water, and at other times may have received purely alluvial deposits.

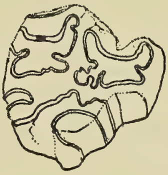
As our knowledge of the land fauna of the California region west of the Sierras and north of Tehachapi is very meagre, the writer has made special effort during the past ten years to secure material which might furnish some information as to this phase of the palaeontologic record. The great thickness of strata in the Orindan and Siestan seems to offer some of the most favorable places to search for vertebrate forms. The beds being so situated that the relation of the vertebrate fauna to the earlier marine Tertiary faunas is determinable, any information acquired is especially valuable for use in connection with work on the correlation of the great marine marginal province and the epicontinental Great Basin province of western North America.

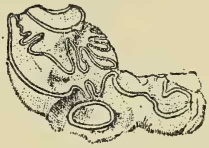
Being easily accessible for investigation, the Orindan and Siestan formations have probably been examined for vertebrate remains more carefully than any other non-marine formations in the California area of the Pacific Coast marginal province. In spite of the efforts put forth, only a very scant fauna has been obtained in the course of the eighteen years since the first systematic search was conducted in these beds. Although the results of our investigation of this fauna are very unsatisfactory, it seems desirable to put the available information on record, as the known relation of these formations to the marine Tertiary of middle California gives unusual significance to all data obtained. It is hoped that presentation of the evidence offered here may serve as a stimulus and a guide to future students of the Orindan and Siestan, so that a much more satisfactory representation of the fauna may be secured.

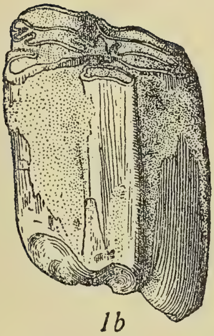
EQUIDAE

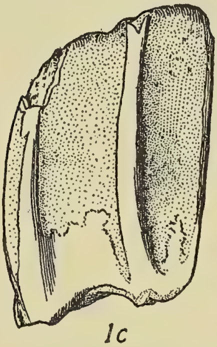
Remains of early horses have been found at two localities in the Orindan beds. No specimens representing this group are certainly known from the Siestan. It is stated that bones of a horse were found in a shaft sunk in Siestan beds on Frowning Ridge near the upper end of Telegraph Cañon, but the writer has been unable to obtain any definite information as to this occurrence. Two teeth representing species near *Neohipparion*, and an astragalus that may well represent a horse of Miocene age have been obtained near Bolinger Cañon. A single tooth was obtained by Mr. J. P. Buwalda from Mr. Williams, who discovered it in extensive Orindan exposures about two and one-half miles from the mouth of Tassajara Cañon, on the southwest side of Mount Diablo. The specimen from Tassajara Cañon and the better preserved tooth from Bolinger Cañon (no. 1324) seem to represent different species.

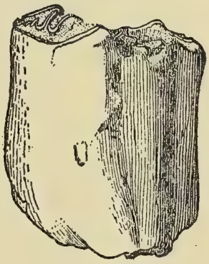












FIGS. 1*a* TO 1*c*. *Neohipparion*, sp. Upper premolar. No. 19830, natural size. Orindan beds, southwest of Mount Diablo.

FIG. 2. *Neohipparion* or *Merychippus*. Upper premolar. No. 1323, natural size. Orindan?, west of Bolinger Cañon.

FIGS. 3*a* AND 3*b*. *Hipparion*(?) or *Neohipparion*. Upper cheek-tooth. No. 1324, natural size. Orindan?, near Bolinger Cañon.

The second specimen (no. 1323) from near Bolinger Cañon is imperfectly preserved, but is possibly different from the other two teeth.

NEOHIPPARION, sp.

Specimen no. 19830, from Orindan beds two and one-half miles southwest of Tassajara Post Office.

This form is represented by a single tooth, P^2 (figs. 1*a* to 1*c*).

The crown is rather large, it has been well cemented, and the outer styles are strong. The flattened protocone is distinct almost to the base. The anterior and posterior fossettes are narrow transversely, and the borders are formed into numerous deep plications. The two fossettes are lightly connected. If this connection is due to lack of wear, it is evident that the crown was not greatly elongated.

This tooth does not agree closely with any form known to the writer, but it does not seem desirable with the present material to give it a special designation other than to recognize it as a distinct form. A species of *Neohipparion* apparently different from that from near Tassajara is known from late Tertiary beds near Ricardo Post Office on the northwestern boundary of the Mohave Desert.

Measurements of Cheek-Tooth No. 19830

P^2, greatest anteroposterior diameter of crown	25.8 mm.
P^2, greatest transverse diameter of crown	21.6
P^2, anteroposterior diameter of protocone	8.2

HIPPARION(?) OR NEOHIPPARION

Specimen no. 1324, from Orindan beds near Bolinger Cañon.

A fragmentary tooth (no. 1324, figs. 3*a* and 3*b*) differs from that seen in the form from Tassajara Cañon in the round protocone and more pronounced plication of the walls of the anterior fossette. This type does not differ greatly from one of the *Neohipparion* specimens from near Ricardo on the Mohave Desert.

Measurements of Upper Cheek-Tooth No. 1324

Greatest anteroposterior diameter	24.2 mm.
Anteroposterior diameter of protocone	6.2

NEOHIPPARION OR MERYCHIPPUS

A specimen (fig. 2, no. 1323) from beds presumably of Orindan age west of Bolinger Cañon is smaller than no. 1324. The protocone is free to the base, the fossettes seem a little wider transversely and show less marked plications than in the specimens tentatively referred to *Hipparion*.

This form may represent a species distinct from the other two forms of the *Hipparion* group or may be included in the genus *Merychippus*.

MEASUREMENTS OF CHEEK-TOOTH NO. 1323

Approximate greatest anteroposterior diameter	18.3 mm.
Approximate greatest transverse diameter	17.7
Greatest anteroposterior diameter of protocone	5.7

PROTOHIPPINE(?) ASTRAGALUS

An astragalus (fig. 4, no. 9858) from near Bolinger Cañon represents a stage of development approximating that of certain Miocene horses. The deeply-cut groove of the trochlea is rather narrow, and is markedly oblique.

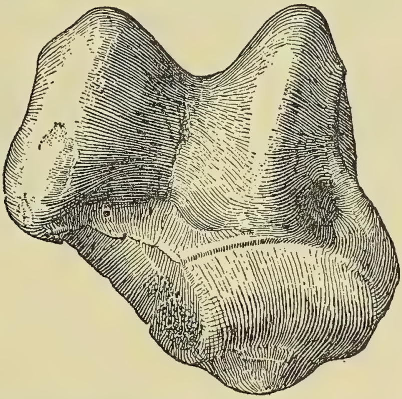


FIG. 4. Protohippine(?) astragalus. No. 9858, natural size. Orindan?, near Bolinger Cañon.

PROSTHENNOPS(?), sp.

Some months ago the class in field geology, working under the direction of Professor Andrew C. Lawson, obtained in fresh-water shales of the Siestan beds near Bald Peak a specimen representing a portion of the skull of a dicotyline form not previously known from California. The specimen consists of a portion of the cranium showing part of the palate with M^2 and M^3 of the right side, and the left cheek-tooth dentition excepting M^1. The teeth are much worn, but enough of the characters are indicated to make possible an approximate determination. The fragment containing the anterior portion of the upper dentition of the left side was separate from the portion with the molar teeth when it came into the writer's hands. It seems to fit imperfectly against the anterior end of the piece with the molars. If this diagnosis of the relation of these pieces to each other is correct, a gap approximately fifteen millimeters long between P^4 and M^2 represents the space occupied by M^1.

The most anterior element of the cheek-tooth series, considered as P^2, is double-rooted. The posterior root is wide transversely and suggests incipient division into two. The crown is relatively wide posteriorly, and shows a large anterior tubercle with a posterior tubercle or cusp which has an anteroposterior diameter not more than half that of the anterior tubercle. It is barely possible that other tubercles were present, but in the present worn condition of the crown no evidence of other features appears. This tooth is near the stage of advance in *Tayassu*, but is perhaps a little less advanced in that the posterior root is narrower and not distinctly divided. If the crown were complete it might show the posterior tubercle or cusp divided into two. This tubercle is, however, smaller than in *Tayassu*.

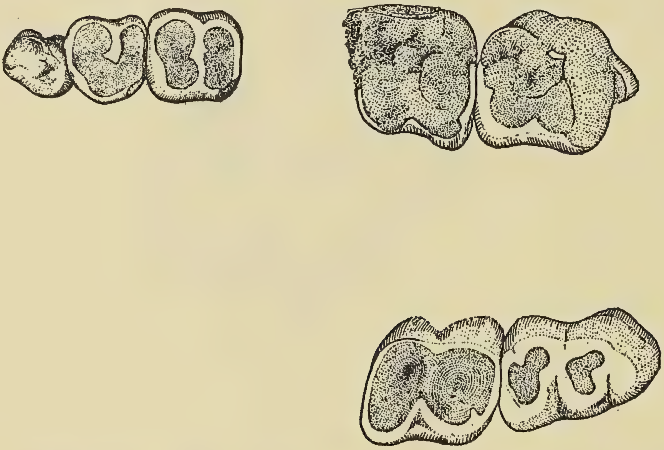


Fig. 5. *Prosthennops(?)*, sp. Upper cheek-teeth. No. 19826, natural size. Siestan beds, near Bald Peak.

The tooth considered to represent P^3 is nearly quadrate, the hypocone region being slightly less developed than the protocone region. The posterior or hypocone-metacone region is narrower anteroposteriorly than the protocone-paracone region. The stage of advance of this tooth is approximately that of *Tayassu*.

P^4 is quadrate in outline, but the hypocone-metacone region is narrower than the protocone-paracone region. The stage of advance is near that of *Tayassu*, with a tendency to show a smaller posterior lobe than in the Siestan form.

The proportions of M^2 and M^3 are much as in *Tayassu* or in *Prosthennops*.

The material available indicates that the form represented by specimen 19826 is near the stage of development of *Tayassu* with the exception that the premolars are slightly less advanced. The character of the upper canines and the length of the diastema are not known.

So far as represented, the characters in this specimen are those of the genus *Prosthennops* known from the Upper Miocene and Lower Pliocene. A specimen from the Pliocene of Thousand Creek in northern Nevada referred to *Prosthennops*[1] resembles this specimen in the general proportions of the teeth, but apparently differs somewhat in the character of the crowns. As nearly as one can judge from the imperfect material, P^2 is quite differently constructed in the two forms. From the evidence available, it does not seem probable that they represent the same species.

Although the material is not at hand for a satisfactory comparison of the Siestan specimen with the *Prosthennops* species known east of the Rocky Mountains, it is probable that the Siestan form is distinct from any of the described species.

MEASUREMENTS	No. 19826
P^2, anteroposterior diameter	9.2 mm.
P^2, transverse diameter	7.9
P^3, anteroposterior diameter	10.8
P^3, greatest width	11.1
P^4, anteroposterior diameter	12.2
P^4, greatest width	12.
M^1, anteroposterior diameter	15.(?)
M^2, anteroposterior diameter	17.
M^2, greatest width	15.
M^3, anteroposterior diameter	18.1
M^3, greatest width	14.4

CAMELIDAE

PROCAMELUS(?), sp.

A portion of the anterior limb (fig. 6, no. 1560) of a camel somewhat larger than the existing llama was found at locality 299 near the middle of the Orindan beds at Bolinger Cañon. This specimen does not show any characters which are recognized by the writer as certainly indicating its specific or generic position, but it is

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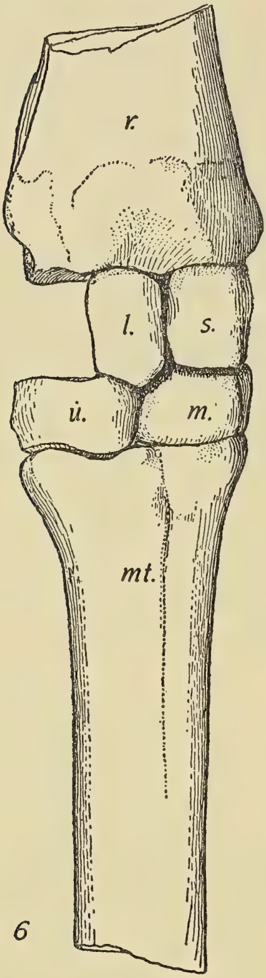
[1] Merriam, J. C., Univ. Calif. Publ., Bull. Dept. Geol., vol. 6, p. 273, 1911.



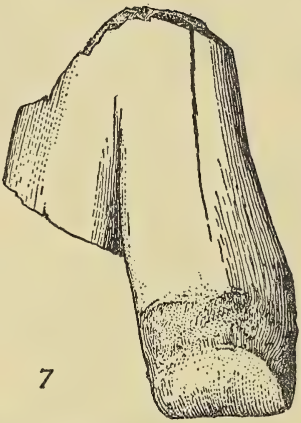


Fig. 6. *Procamelus*(?), sp. Portion of anterior limb. No. 1560, × ½. Orindan, Bolinger Cañon.

Fig. 7. *Pliauchenia*(?), sp. Portion of cannon bone. No. 1982, × ½. Siestan, Siesta Valley.

evidently near *Procamelus*, a genus well known in the Upper Miocene of the Great Plains and Basin regions. The species represented by this specimen is larger than the forms found in the

Basin region, but the dimensions shown here are approached by *Procamelus robustus* of the Great Plains.

MEASUREMENTS

Radius, greatest transverse diameter of distal end	62.5 mm.
Cannon bone, greatest transverse diameter of proximal end	58.6
Scaphoid, greatest anteroposterior diameter	38.8
Lunar, greatest height	31.
Magnum, greatest anteroposterior diameter	34.7

PLIAUCHENIA(?), sp.

A fragment of the distal end of a cannon bone (fig. 7, no. 1982) was obtained by J. P. Buwalda at locality 707 in the Siestan beds of Siesta Valley, in the hills immediately to the east of Berkeley. This specimen, though very fragmentary, certainly represents a large camel approximating the dimensions of the Recent *Camelus*. It evidently belongs to a form considerably larger than the species from the Orindan of Bolinger Cañon and probably represents a species of the genus *Pliauchenia*, a large camel of a more advanced stage of development than *Procamelus*. *Pliauchenia* is a characteristic form of late Miocene to Pliocene time.

MEASUREMENTS

Transverse diameter of cannon bone 60 mm. above the distal end	64. mm.
Thickness of cannon bone 60 mm. above the distal end	26.6
Least width of one of the two distal divisions of the cannon bone below the point of fusion	39.

TETRABELODON(?), sp.

Remains of mastodon-like forms have been found by R. E. Dickerson in the upper portion of the Orindan section of Bolinger Cañon, and by J. P. Buwalda in the lower portion of the Orindan section near Tassajara Cañon on the south side of Mount Diablo. The material is all very fragmentary and is not susceptible of even certain generic determination.

The specimen from Bolinger Cañon consists of fragments of cheek-teeth and portions of a lower jaw of an animal of considerable size.

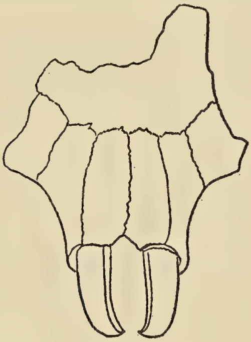
The specimens from near Tassajara Cañon include fragments of teeth. They represent an animal of the mastodon type but the fragments are too imperfect for certain generic identification.

Dipoides lecontei (Merriam, J. C.)

From Siestan beds near Bald Peak.

The type specimen (figs. 8*a* to 8*c*), consisting of the anterior part of a skull with three cheek-teeth on each side, was discovered in the Siestan beds near Bald Peak. A single lower molar has since been found in the same beds.

This form was originally described under the generic name of *Sigmogomphius*, on the assumption that there were but three superior cheek-teeth. In the original description, the writer called attention to the similarity of the dentition to that of *Eucastor* Leidy, but separated it from that genus owing to the difference in pattern of the enamel folds. Comparative material was not available at that time, and the writer was not aware of the extent of change possible in the tooth pattern of these forms with wear. There seems now good reason to believe that a worn *Sigmogomphius*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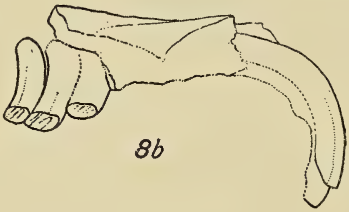
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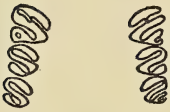
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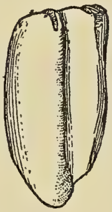
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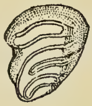
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Figs. 8*a* to 8*c*. *Dipoides lecontei* (Merriam, J. C.). Type specimen natural size. Fig. 8*a*, superior view of skull; fig. 8*b*, lateral view of skull; fig. 8*c*, superior cheek-teeth. Siestan beds, near Bald Peak.

Figs. 9*a* and 9*b*. *Dipoides*, sp. P_4, × 2. Fig. 9*a*, outer side; fig. 9*b*, occlusal view. Siestan beds, near Bald Peak.

molar would develop a tooth pattern similar to that of *Eucastor*, and that both *Sigmogomphius* and *Eucastor* are not to be distinguished from the Old World genus *Dipoides* Jager. It is, however, worth noting that the reduction of the posterior molars in some of these forms suggests a possible reduction of the cheek-tooth formula to three, as was assumed for the genus *Sigmogomphius*. It is not certain that this reduction occurs in *Dipoides lecontei*, as the last molars may have been lost from the type specimen.

A single lower cheek-tooth, P_4 (figs. 9*a* and 9*b*), from the Siestan beds resembles the European type of *Dipoides*, and the tooth pattern shows close similarity to that of a somewhat larger form found in the Thousand Creek beds of northern Nevada.

Lepus, sp.

Fragmentary remains of two rabbits are known from fresh-water beds in the hills near Berkeley. They consist of a lower tooth (no. 19827), from the Siestan beds near Bald Peak, and a portion of a lower jaw from an Orindan exposure in Wildcat Cañon. It is doubtful whether the two specimens represent the same species, but neither one is certainly specifically determinable.

Plant Remains

At several localities in the Siestan formation, imperfectly preserved plant remains have been found in clays and sands containing fresh-water shells, a few land shells, and remains of land vertebrates. The plant remains consist largely of fragments of stems and leaves of rushes and grass, but include also a few leaves of trees. Professor W. L. Jepson, who has examined these specimens, considers the leaves as representing *Acer*, sp., *Sterculia* or *Acer?*, and *Dirca*, sp.

Age of the Orindan and Siestan Vertebrate Faunas

Although the vertebrate remains from the Orindan and Siestan are probably obtained from horizons comprising quite a wide range in time, they represent collectively the greater part of the known land fauna of this region in a period following the San Pablo Miocene and preceding the Pleistocene. Such field work as has been done up to this time does not lead us to expect large collections from these formations, though the discovery of strata rich in determinable remains is always possible. The Siestan beds seem to offer a possible fruitful field for future collecting.

The mammalian remains known from both the Orindan and Siestan up to the present time all represent forms such as might be expected in the late Miocene or in the earliest Pliocene, but it will be necessary both to have better material from the Orindan and Siestan and to have well-known faunas of western Miocene and Pliocene for comparison before the last word on the age determination can be pronounced.

The late Tertiary mammalian faunas which are most available for comparison with the forms from California are those of the Basin region, including the Tertiary beds of the Mohave Desert region of California, those of the Cedar Mountain region of Nevada, and the Thousand Creek beds of northern Nevada. All of these faunas are as yet imperfectly known, but there seems reason for considering the Thousand Creek as representing early Pliocene, and the deposits of the Mohave and Cedar Mountain regions as at least in part near late Miocene.

Compared with these faunas there seems in some respects less suggestion of similarity with Thousand Creek than with the other two. On the other hand, there is no indication of identity with the so-called Mohave fauna of the Barstow region. The beds referred to the Rosamond series, in the Ricardo region on the western border of the Mohave Desert, contain a fauna with *Neohipparion*, suggesting the Orindan fauna. The Ricardo fauna is possibly somewhat later than that of the best known horizon containing the Mohave fauna in the Barstow syncline.

Considering the indefiniteness of all the factors concerned, one would not seem justified in being more definite than to state that the Orindan and Siestan faunas are near a late Miocene stage. When the faunas of the two formations are better known, it may appear that more than one stage is represented.

Transmitted June 28, 1913

AN OCCURRENCE OF MAMMALIAN REMAINS IN A PLEISTOCENE LAKE DEPOSIT AT ASTOR PASS, NEAR PYRAMID LAKE, NEVADA

INTRODUCTION

SOME months ago Professor J. C. Jones of the University of Nevada kindly offered to the writer for examination a small collection of mammalian remains obtained by him at Astor Pass, Nevada, in gravel deposits which were evidently formed along the shore of the Pleistocene Lake Lahontan. As the physical history of the Nevada region during a portion of Pleistocene time has been the subject of exhaustive discussion, while of the biological history very little has been known, the specimens secured by Professor Jones are of unusual importance. Particularly is this true as the occurrence evidently represents one of the phases of the great lake, Lahontan.

The writer is much indebted to Professor Jones for the opportunity to examine this interesting collection and for a description of the occurrence of the specimens. The origin of the deposits in which the mammalian fossils occur is fully discussed by Professor Jones in a recent paper.[1] In addition to the specimens obtained by Professor Jones from the gravels at Astor Pass, it has been the writer's privilege to examine a considerable portion of a horse skull found in a tufa deposit at Astor Pass. For the use of this specimen, the writer is much indebted to Mr. William Hood, chief engineer of the Southern Pacific Railroad, who secured the skull during the course of the excavations.

Professor Jones informs the writer that the material obtained by him was found in a railway cut in gravel deposits at Astor Pass four miles west of the north end of Pyramid Lake. The gravel beds at this point lie on the western slope of a narrow ridge of andesite, and are largely composed of andesitic pebbles evidently derived from this

University of California Publications, Bulletin of the Department of Geology, vol. 8, no. 21, pp. 377–384, pl. 41, February 25, 1915.

[1] Jones, J. C., Science, n. s., vol. 40, pp. 827–830, 1914.

outcrop. The gravels are covered by a four-foot layer of dendritic tufa similar to that found above the thinolite tufa in the Lahontan deposits. A few isolated crystals of thinolite were found at the base of the gravel deposit. In the midest of the gravels, and about ten feet below the dendritic tufa cap, there is a layer of typical lithoid tufa several inches in thickness. Judging from all the evidence available, Professor Jones is convinced that the gravel deposit was formed along the shore of Lake Lahontan.

The occurrence of the fossil remains is described by Professor Jones as follows:

> The majority of the bones were found in the outward end of the bar and in the upper twenty feet of the deposit. All of them were isolated from each other and no complete skeletons were reported. Many of them were more or less coated with the dendritic tufa and in excavating a ditch through a layer of the dendritic tufa one hundred and fifty feet to the east of the deposit, a skull of a horse was found in the tufa. In addition to the bones secured, a large number, including several skulls and a large leg-bone described as being the size of an elephant's, were uncovered and afterwards lost.
>
> It is evident from the disjointed condition of the bones that they were washed about by the waves to a considerable extent before their final burial in the gravels. Two hypotheses may be considered as to the time when the animals lived: first, they may have existed in pre-Lahontan time and been first covered by an earlier deposit that was reworked by the waters of Lahontan; second, they may have lived in Lahontan time and were buried in the deposits of that lake.
>
> As the deposit is composed exclusively of the basic andesite found in the ridge to the immediate south, evidence of a deposit earlier in age should be found along its flanks. While it was impossible in the time available to entirely cover the ridge, no such evidence could be found within a mile of the gravels and as no evidence of shore drift could be found south of the end of the bar, it is not probable that the bones and gravel could have been washed from a pre-existant deposit. An alternate suggestion would be that the gravel deposit was formed in an earlier lake and was simply worked over by the waters of Lake Lahontan. If this were true, the entire bar must have been worked over, for no evidence could be discovered in the exceptionally good exposures of the cut and gravel pit of any structural discordance. The tufas are entirely conformable with the gravels and it is known that the thinolite at least is characteristic of the Lahontan period in this basin. Further, if the deposit was worked over in its entirety, it seems remarkable that the bones should be limited practically to the upper and outer parts of the bar rather than being promiscuously scattered through the deposit. The only other possible suggestion is that as the waters of Lahontan rose and fell, they failed to leave their impress on the bar, which seems to be beyond the realms of probability.
>
> Under the circumstances, as far as our present knowledge goes, there seems

no other conclusion probable than that the animals represented by the bones found in the gravels lived and died along the shores of the former lake and were buried in its sediments.

The forms obtained in the deposits at Astor Pass include the following:

Felis atrox Leidy.
Camelid, near Camelops?
Equus, sp.
Fish, vertebrae, indeterminate.
Bird, vertebra, indeterminate.

The specimen referred to *Felis atrox* seems not to differ essentially from corresponding teeth of large individuals of this gigantic feline from the Pleistocene of Rancho La Brea. The camel remains are of a large form near the type of the camel of Rancho La Brea. The single tooth of a horse obtained from the gravels at Astor Pass by Professor Jones might, if taken alone, be referred to the Rancho La Brea species *Equus occidentalis*. In some of its characters the dentition of the specimen obtained from the tufa deposit by Mr. Hood resembles *E. pacificus*, a species unknown at Rancho La Brea, but represented in the Pleistocene of Fossil Lake in eastern Oregon. The Astor Pass specimen is not certainly to be referred to *E. pacificus* and may be a distinct form.

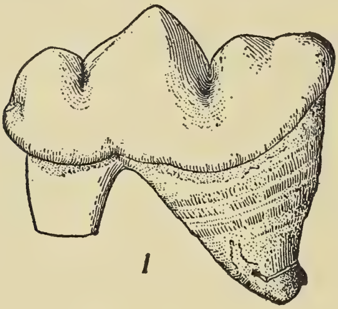
The few forms represented in the Astor Pass gravels represent a Pleistocene stage not remote from that of Rancho La Brea. The fact that the horse skull does not correspond in type to the average of specimens from Rancho La Brea, and is comparatively near the characteristic species of Fossil Lake, may mean that this fauna represents a stage different from that of Rancho La Brea, or that in Rancho La Brea time the horses of the middle and northern Great Basin region were different from those of the southern Pacific Coast region. The succession of mammalian faunas of the Pacific Coast and Great Basin Pleistocene is not yet sufficiently well known to permit the construction of a satisfactory chronology, and it is not yet possible to state to what extent the faunas of various localities overlap.

As very little has been known of the fauna inhabiting the Great Basin province during the time of deposition of the Lahontan sediments, the material obtained by Professor Jones from Astor Pass gives us a distinctly important contribution to our knowledge of this subject.

Description of Material

FELIS ATROX Leidy

An upper carnassial (fig. 1) of a very large cat from the Astor Pass gravels represents a form not distinguishable from *Felis atrox* of the Rancho La Brea Pleistocene. The measurements of the specimen approximate those of the largest male individuals from Rancho La Brea.



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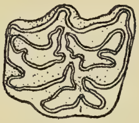

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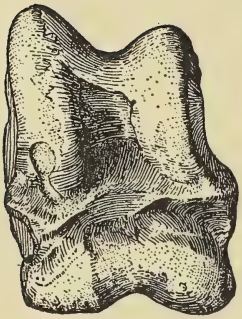

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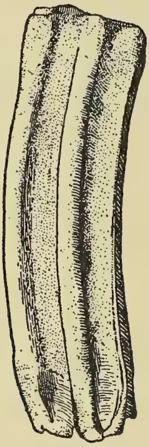


3b

Figs. 1 to 3*b*, from Pleistocene gravels, Astor Pass, Nevada.

Fig. 1. *Felis atrox* Leidy. P^4, outer side. No. 21699, natural size.

Fig. 2. Camelid astragalus. No. 21385, × ½, superior view.

Figs. 3*a* and 3*b*. *Equus*, sp. M^2?, No. 21698, × ½. Fig. 3*a*, occlusal view; fig. 3*b*, outer view.

Measurements

	No. 21699 Astor Pass	No. 14001 Rancho La Brea
P^4, greatest anteroposterior diameter	44.3 mm.	43.
P^4, greatest transverse diameter across deuterocone	20.9	21.5
P^4, height of protocone	22.	....

CAMELID, near CAMELOPS?

An astragalus (no. 21385, fig. 2) represents a camel near *Camelops*, the form known at Rancho La Brea.

DIMENSIONS OF ASTRAGALUS, No. 21385

Greatest anteroposterior diameter	80.5 mm.
Greatest width at distal end	54.

A fragment of the distal end of a metapodial represents a large camel. It is too incomplete for determination.

EQUUS, sp.

The specimen (pl. 41) which Mr. William Hood kindly placed at the disposal of the writer, comprises the portion of the skull situated between the anterior borders of the orbits and the anterior ends of the nasals. The cheek-tooth dentition is complete with the exception of M^3. The teeth are unusually well preserved and are in an early stage of wear. P^4 shows beginning wear, but the enamel pattern is not completely outlined.

The enamel pattern is distinctly more complex than that seen in the Rancho La Brea specimens of *Equus occidentalis*, and approaches the degree of complexity found in *E. pacificus*. The anterior and posterior fossettes may be somewhat wider than in the type of *E. pacificus*. The form of the protocone may be approximated in either *E. pacificus* or *E. occidentalis*. The dimensions average slightly larger than those of *E. occidentalis* of Rancho La Brea, although some individuals of the Rancho La Brea species may show measurements slightly exceeding those of the Astor Pass specimen. The measurements are somewhat smaller than those of the type of *E. pacificus*, but may fall within the limits of variation in that species.

As yet the variation within *Equus pacificus* is not sufficiently well known to make possible an exact statement of the characters of that species. In general, it would seem that the cheek-teeth are distinguished from those of *E. occidentalis*, as represented in the Rancho La Brea collections, by large size, narrow fossettes, and more complicated pattern of the enamel bordering the fossettes and the outer end of the post-protoconal valley.

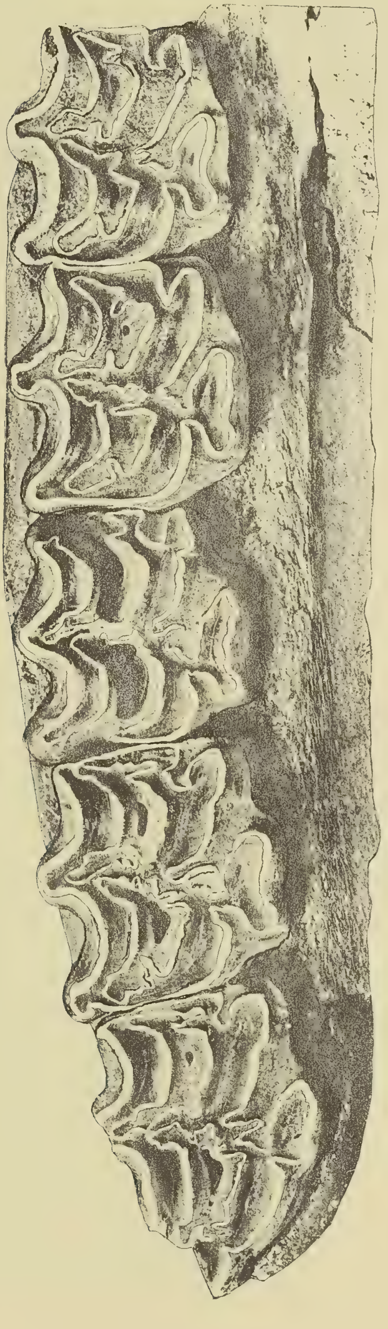
As nearly as one can judge from the material available, the Astor Pass specimen resembles *Equus pacificus* more closely than do any of the horses as yet observed in the Rancho La Brea collections. It is not clear that this form is certainly to be referred to *E. pacificus.* More information on the range of variation in that species is necessary and especially is it desirable to have more definite knowledge of the characters separating it from *E. occidentalis.*

A single cheek-tooth (no. 21698, figs. 3*a* and 3*b*) from Astor Pass, kindly presented by Professor Jones, represents a type with dimensions smaller than those in the skull obtained by Mr. Hood. The fossettes are rather narrow. The enamel is somewhat less complicated than that in the skull specimen. This specimen taken by itself might be referred to *Equus occidentalis*, but the writer is inclined to think that it represents the same species as that seen in the skull specimen.

MEASUREMENTS

	Hood Specimen Astor Pass	No. 21698
Length of upper premolar series, without P^1	107. mm.	....
P^2, anteroposterior diameter	40.4	....
P^2, transverse diameter	28.4	....
P^3, anteroposterior diameter	34.	....
P^3, transverse diameter	31.2	....
P^4, anteroposterior diameter	31.	....
P^4, transverse diameter	29.	....
M^1, anteroposterior diameter	30.6	....
M^1, transverse diameter	29.4	....
M^2, anteroposterior diameter	31.5	30.5
M^2, transverse diameter	27.5	26.8
M^2, length of crown	....	*a*103.

Transmitted October 24, 1914



Equus, sp. Dentition of specimen obtained from Pleistocene tuff deposit at Astor Pass, Nevada, by Mr. William Hood. Superior cheek-teeth, natural size.

EVIDENCE OF MAMMALIAN PALAEONTOLOGY RELATING TO THE AGE OF LAKE LAHONTAN

CONSIDERING the importance of the deposits of Lake Lahontan in Pleistocene history of North America, it is surprising that exceedingly little palaeontologic evidence as to age of these beds has been obtained up to the present time. The mammal material available to Russell[1] in the course of his exhaustive study of these deposits consisted of a very few specimens representing four forms, for only one of which a specific determination has been suggested. The remains known to Russell represented an elephant, a horse, a bison, and a camel. A spearhead, found embedded in strata presumed to be of Lahontan age, was also reported. All of the forms known from the Lahontan were assumed to occur in the upper portion of the lake beds series and to have been buried subsequent to the "intermediate stage" of Russell.

Of greater importance than the scattered mammal bones secured in the Lahontan beds by Russell is a small collection obtained in 1914 by Professor J. C. Jones of the University of Nevada,[2] from deposits occurring at Astor Pass, four miles west of Pyramid Lake, and considered to represent Lahontan terraces. In the gravels of these deposits Professor Jones secured remains representing three or four mammals. One species is clearly determinable as *Felis atrox*, the largest known member of the true cat group. A second is a camel near *Camelops*, not differing noticeably from *Camelops hesternus*, well known in the Pleistocene deposits of Rancho La Brea. A considerable part of a skull represents a horse, in which the dentition is slightly different from that of the Rancho La Brea *Equus occidentalis*, and approaches in some respects that of *E. pacificus* of the Fossil Lake Pleistocene of eastern Oregon. A single

Paper presented before the American Geographical Society, at New York City, December 29, 1916. *University of California Publications, Bulletin of the Department of Geology*, vol. 10, no. 25, pp. 517–521, September 4, 1918.

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[1] Russell, I. C., U. S. Geol. Surv. Monographs, vol. 11, p. 238, 1885.

[2] See Merriam, J. C., Univ. Calif. Publ. Bull. Dept. Geol., vol. 8, pp. 377–384, 1915.

separate upper molar tooth of a horse from the same deposit is nearer in type to *E. occidentalis.*

A third important collection representing Pleistocene mammal faunas of the Great Basin province is the material secured by Buwalda[3] in the deposits of Manix Lake, a small body of fresh water which formed in the Mohave Desert region in Pleistocene time. The Manix collection includes six species of mammals and one or more species of birds, together with four types of fresh-water mollusks. Of these forms the mammals include: (1) a large horse certainly *Equus;* (2) a somewhat smaller horse; (3) a large camel; (4) a small camel; (5) a fragment representing a proboscidean; (6) an antelope of unknown species.

The conditions which governed expansion of the lake in which the Manix deposits were formed resemble in a manner those which controlled variation of Lake Lahontan, as described by Russell. It is possible that the climatic changes which influenced Lake Manix are identical with those reflected in Lahontan history, and the Manix fauna may be of the same stage as that of Lahontan.

A fourth Pleistocene fauna from the Great Basin province is that of Fossil Lake in eastern Oregon, obtained in sandy deposits, the stratigraphic relations of which are not satisfactorily described. There has been some mingling of Recent and Pleistocene remains in the lists of material secured from this locality; but after all necessary subtractions are made, one of the most important Pleistocene mammal and bird faunas of America remains, including a large number of mammals and over fifty species of birds.

Evidence as to the age of the Fossil Lake fauna is to a certain extent contradictory. According to Gilbert[4] and to Russell, the stage of accumulation of the Fossil Lake deposits is approximately that of Lake Lahontan and Lake Bonneville. Gilbert considered that the highest level of Lake Bonneville corresponded approximately to the last stage of advance of the Wasatch glacier. Similar evidence seems to be furnished by the relation of the highest level of Pleistocene Lake Mono to the lowest moraines of the glacier on the east side of the Sierras. If these suggestions are approximately correct, the last stage of Lahontan and Bonneville, approximating the stage of Fossil Lake, would perhaps correspond to the Wisconsin or last glacial epoch.

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[3] Buwalda, J. P., Univ. Calif. Publ. Bull. Dept. Geol., vol. 7, pp. 443–464, 1914.

[4] Gilbert, G. K., U. S. Geol. Surv. Monographs, vol. 1, p. 395, 1890; Russell, I. C., *op. cit.*, vol. 11, 1885.

In his study of Lake Bonneville, Gilbert gave particular attention to the problem of age determination of the deposits and made careful comparison of the sediments of the Bonneville and Lahontan stage with those of Fossil Lake in south central Oregon. He considered that in the Fossil Lake region, "just as in the Bonneville and Lahontan basins, the physical relations indicate that the shore lines and lacustrine sediments are co-ordinate products of the same expansion of lake waters." He stated further that "each of the old lakes thus demonstrated stands witness to climatic oscillation, and their geographic relations leave no room for question that they pertain to the same climatic oscillation, and therefore have the same date."

The evidence of faunas as interpreted by Osborn and by Hay would fix the age of the Fossil Lake deposits as early Pleistocene. In this palaeontologic determination one of the most important arguments is the absence of bison remains from these deposits, which were evidently formed in an open plains region where bison would be expected to occur. This peculiarity is offset to some extent by the fact that the large wolves of the Fossil Lake beds seem to be exclusively of the modern timber wolf type. The great dire wolf, *Aenocyon dirus*, has not been recognized in the Fossil Lake fauna, although it is exceedingly abundant at Rancho La Brea and seems to be represented at Potter Creek Cave. Difference in the types of wolves might be due to the northern origin of the modern timber wolves, and to its restriction throughout Pleistocene time to the northern portion of the West Coast region. Within historic time the timber wolf has not been known in middle and southern California. This would not, however, account for its failure to overlap in range with *Aenocyon dirus* in the Great Plains region. Of the total Fossil Lake fauna 66 per cent of the mammals and 34 per cent of the birds are extinct. These percentages are probably not finally determinative of age, but they suggest a stage comparable to that of Hay Springs or Rancho La Brea and earlier than Conard Fissure or Samwel Cave.

Compared with the Rancho La Brea fauna that of Fossil Lake is characterized by absence of *Bison*, which are abundant at Rancho La Brea, and were evidently late arrivals in America. This peculiarity is balanced by absence of the small antelope, *Capromeryx*, and the imperial elephant, early types characteristic of Rancho La Brea. *Equus pacificus*, the common horse of Fossil Lake, is apparently a more specialized form than *E. occidentalis* of Rancho La Brea, and the prong-horn *Antilocapra* represented at Fossil Lake is apparently a specialized descendant derived from a stock near the Rancho La Brea *Capromeryx*. It may be that the Fossil Lake assemblage is not older than that of Rancho La Brea, but is merely a contemporaneous northern phase of the same fauna.

The absence of bison from the Fossil Lake fauna may be sufficient warrant for considering it older than the upper Lahontan stage, but this item may not be of greater value in separating the time of deposition of the two sets of deposits than is the physical evidence used by Gilbert to prove their contemporaneity.

If Gilbert is correct in his correlation of Fossil Lake with Lahontan and Bonneville, the Lahontan fauna belongs to a time separated from the present by a period of widespread extinction of organic types and by evolution or introduction by migration of an almost entirely new mammal series, as two-thirds of the Fossil Lake mammal species are extinct and the stage as a whole does not appear like the latest Pleistocene.

In some respect the closest resemblance of the few mammal fragments from the Lahontan is to the fauna of Rancho La Brea. Of the known Lahontan fauna—*Elephas columbi?*, *Equus* near *pacificus*, *Equus* near *occidentalis*, *Bison*, sp., *Camelops*, sp., *Felis atrox*—all of the forms so far as known, with the exception of the horse near *E. pacificus*, are found at Rancho La Brea. It seems possible that the Lahontan fauna may be representative of a period including the Fossil Lake and Rancho La Brea stages. On this basis it would appear that, whatever the more exact correlation, the Lahontan stage represents a time when the life of this region and that of North America in general was made up of mammal types of which from 60 per cent to 70 per cent have since become extinct and are replaced by new types.

We are not of course able to make an exact correlation for the whole of North America in Pleistocene time, but we know that many of the types included in the Rancho La Brea and Fossil Lake assemblages had a very wide geographic distribution, and it seems that a change such as has occurred since Rancho La Brea and Fossil Lake time is typical of a faunal change over a large part of America.

That an extinction of 66 per cent of the mammals in any fauna might occur in a very short time one might readily grant, but the origin of the new fauna replacing it is not so readily conceived. We may, I believe, assume that the existing fauna of the Lahontan region is not merely a remainder from a large Pleistocene fauna. The origin of the present fauna is not to be accounted for in this manner more easily than one would account for the origin of the existing earth fauna as a remainder from a Mesozoic life series gradually diminishing from period to period. The present fauna is to be accounted for in some part as a remainder and in part as a new development either out of ancestral American forms or out of immigrants from other regions. One might, of course, assume that the existing faunal types arose very recently as mutants developing in response to some great shock given by a physical change such as a great modification of climate, but no evidence has been advanced indicating that such change has ever taken place within a short time measured in terms of years. The rate of change of faunas is fairly known in relation to rate of sedimentation, and there seems to be on record no case in which such an extreme modification of life as is noted between the Rancho La Brea stage and the present has taken place in less than a considerable period measured in terms of deposition.

If we assume that the present fauna peopled America by migration, we encounter an obstacle no less difficult to overcome than that presented by rapid evolution without change of geographic situation, as migration from any other continent involves the crossing of great barriers of topography, and belts of varying temperature at least as important as hindrances to migration as are those of relief. Such migration as would be required presumably involves nothing less than general specific change of the migrating types, and a biological reorganization process which would take place slowly in the extension of the group by migration transverse to physical barriers.

The problem of fixing the date of the Lahontan fauna seems the same as that for other Pleistocene faunas containing a large percentage of extinct forms. An interpretation of the history of the

Lahontan region as shorter than that commonly accepted, which measures the time in long periods expressed in terms of years, involves explanation of the extinction of a great variety of forms over a wide area, and appears to require the relatively sudden repeopling of this area either by more rapid evolution than we have reason to consider probable, or by a more rapid migration across barriers of temperature or of topography than we have reason to believe could occur without evolutionary changes in the migrating fauna.

REMAINS OF LAND MAMMALS FROM MARINE TERTIARY BEDS IN THE TEJON HILLS, CALIFORNIA

Occurrence and Age of Vertebrate Remains

In the fall of 1911 Mr. R. W. Pack, of the United States Geological Survey, obtained a number of fragmentary mammalian remains in a marine deposit situated in the Tejon Hills at the southern end of the Great Valley of California. The beds in which this material was obtained lie immediately to the north and west of the Tehachapi Range, and are separated by a distance of between twenty-five and thirty miles from the western side of the Mohave Desert, in which Tertiary mammal-bearing deposits of considerable extent are known.

In a paper read before the Pacific Coast Palaeontological Society in 1912 the statement[1] was made that the material obtained by Mr. Pack represented mammalian types resembling an imperfectly known fauna from the Mohave Desert. It was stated that the known invertebrate fauna in the formation containing vertebrate remains was generally presumed to represent a Lower Miocene stage. It was also noted that the fauna in the Tertiary mammal beds of the Mohave region was apparently not older than Upper Miocene, and that a question was raised as to the correspondence of the time-scale of the California marine series with that of the continental deposits east of the Sierras.

Since the first study of the vertebrate material secured in the Tejon Hills by Mr. Pack, small collections from the same localities have been obtained for the University of California by R. C. Stoner and J. P. Buwalda. Though the total amount of material secured is small, it is desirable to place on record such information as is now available, in the hope that it may be of assistance in a study of the

University of California Publications, Bulletin of the Department of Geology, vol. 8, no. 13, pp. 283–288, February 25, 1915.

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[1] Merriam, J. C., and Pack, R. W., Proc. Palaeont. Soc. Bull. Geol. Soc. Amer., vol. 24, p. 128, March, 1913.

problem of correlation among the West American Tertiary formations.

Through the kindness of the Director of the United States Geological Survey and of Mr. Pack, it has been the writer's privilege to make an examination of the original vertebrate collection from the Tejon Hills and to present the following description with a discussion of the University of California material from this region.

The majority of investigators who have examined the Tertiary beds of the Tejon Hills are of the opinion that some of the vertebrates occur in a formation corresponding to the "Temblor," or the commonly recognized Lower Miocene of the Kern region to the north.

Mr. Pack, who has carefully studied the section of the Tejon Hills, informs the writer that the Tertiary beds in this area are separable on lithologic grounds into a lower division, comprising 800 to 1000 feet of grayish sand and gravel with some indurated calcareous sandstones; and an upper division of somewhat greater thickness consisting of reddish clay, sand, and coarse gravel. According to Mr. Pack the whole of the lower division should probably be correlated with the beds referred to the Lower Miocene in the Temblor Range, and the upper division appears to be of somewhat later age. Horse teeth near the *Merychippus* type were found in the uppermost part of the lower division. Bones of *Merycodus* and a tooth of a horse near the *Hipparion* type probably came from the basal part of the upper division.

Mr. Robert Anderson[2] in reporting on the Tertiary of the Tejon Hills makes the following statement:

"Marine fossils discovered in the Tertiary sand, gravel, and clay of the Tejon Hills suggest that the beds are contemporaneous with the Santa Margarita (?) formation (upper middle Miocene) of the Temblor Range. The fauna, however, is of a type occurring also in the lower Miocene, and a definite correlation can not yet be made. The fact that these beds lie directly upon the crystalline rocks favors the supposition that they are a continuation of the lower Miocene beds occupying a similar position on Kern River."

Intensive study of the invertebrate fauna of this region will be necessary before a fully satisfactory correlation with the other marine Tertiary formations of the San Joaquin Valley can be made. It is possible that faunas representing both the "Santa Margarita" and "Temblor" stages are present in the Tejon Hills area.

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[2] Anderson, Robert, U. S. Geol. Surv. Bull., 471, p. 121, 1912.

The mammalian collections obtained in the Tejon Hills consist of very fragmentary material including a small number of teeth and limb-bones. The forms represented are the following:

Merychippus, sp.
Hipparion or Merychippus, sp.
Merycodus, sp.
Rhinocerotid? remains.
Isurus, near planus (Agassiz)

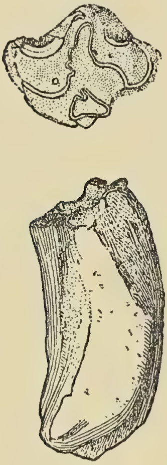
The horse remains from the lower beds are near the stage of evolution of Merychippus-like forms of the Barstow fauna in the Mohave Desert immediately to the east. They are less advanced than any available forms of the Ricardo fauna representing the next faunal stage following the Barstow in the known mammalian succession of the region west of the Wasatch. An equid form from Tejon Creek is near *Hipparion* and may represent a second fauna. The antelope-like *Merycodus* bones are scarcely to be distinguished from corresponding elements of *Merycodus necatus* of the Barstow fauna. The phalanges may be slightly more slender than in the average *M. necatus* from the Barstow fauna. A Ricardo species has characters near those of the Barstow type, and is also not clearly separable from the Tejon Hills form.

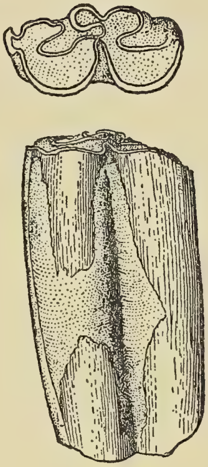
So far as can be determined from the material available, the Tejon Hills collection represents one or more stages not younger than the earliest Pliocene and not older than the Middle Miocene fauna of the Merychippus zone of the "Temblor" beds in the North Coalinga region on the western border of the San Joaquin Valley.

Description of Material

PROTOHIPPINE FORMS

A specimen (fig. 1) obtained by Mr. Pack from the west side of Comanche Creek one-half mile east of Signal Hill is a slightly curved, well-cemented tooth which has suffered some wear. The connection of the fossettes at the adjoining borders indicates that the stage of wear is not advanced. The protocone is discrete and shows no suggestion of connection with the protoconule. The fossettes are not especially wide transversely, and their enamel borders are relatively simple. This tooth resembles the *Hipparion* group in the character of the protocone, but not in the nature of the fossettes. It agrees approximately in structure with specimens of Merychippus-like forms of the Barstow fauna, but is not clearly separable from an undescribed species of the Merychippus zone in the "Temblor" beds north of Coalinga on the west side of the San Joaquin Valley.[3] The cement covering is possibly a little thicker than on the "Temblor" form.





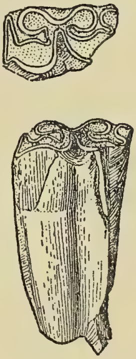


Fig. 1. *Merychippus*, sp. Upper cheek-tooth, posterior and occlusal views, natural size. From west side of Comanche Creek, Tejon Hills, at the southern end of the San Joaquin Valley, California. (Lower division?)

Fig. 2. *Merychippus*, sp. P_4?, outer and occlusal views. No. 21484, natural size. From Comanche Creek, Tejon Hills, southern end of the San Joaquin Valley, California. (Lower division?)

Fig. 3. *Hipparion* or *Merychippus*, sp. M_1?, outer and occlusal views. No. 21566, natural size. From the south side of Tejon Creek, Tejon Hills region, southern end of the San Joaquin Valley, California. (Upper division?)

A lower tooth, P_4?, no. 21484 (fig. 2), collected at Comanche Creek, locality 430, in the Tejon Hills, by R. C. Stoner is not larger than P_4 of an undescribed *Merychippus* from the Barstow fauna, and has much the same roughened surface. The metaconid-metastylid column is of the anteroposteriorly short *Merychippus* type, but is a little more flattened than in average specimens of that group. The valleys anterior and posterior to this column are much narrower transversely than those noted by the writer in specimens from the Barstow fauna. This tooth is nearest the type of the advanced *Merychippus* forms of the Barstow fauna, but may be specifically distinct from any Barstow species. It may be more advanced than the Barstow species.

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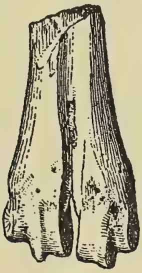
[3] See Merriam, J. C., Science (n.s.), vol. 40, pp. 643–645, 1914.

A small lower cheek-tooth, M_1?, no. 21566 (fig. 3), of a protohippine species obtained on the south side of Tejon Creek by Mr. Buwalda represents a type near *Hipparion*. The dimensions of the tooth approximate those of some *Merychippus* forms of the Barstow fauna. The type of tooth seen in the specimen may also be near that of a *Merychippus* species of the Merychippus zone in the "Temblor" beds of the North Coalinga region on the west side of the San Joaquin Valley. In specimen 21566 the metaconid-meta-



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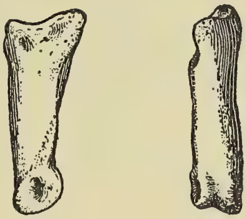
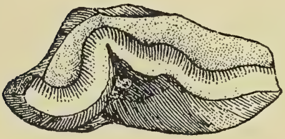


5a 5b

FIG. 4. *Merycodus*, sp. Distal end of metatarsus, anterior side, natural size. From the Tejon Hills, at the southern end of the San Joaquin Valley, California. (Upper division?)

FIGS. 5*a* AND 5*b*. *Merycodus*, sp. Proximal phalanx, natural size. Fig. 5*a*, lateral view; fig. 5*b*, superior view. From the Tejon Hills, at the southern end of the San Joaquin Valley, California. (Upper division?)



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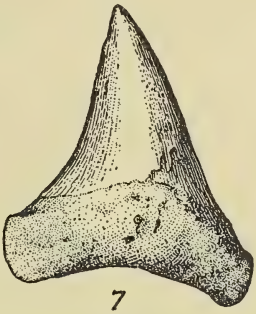

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FIG. 6. Fragment of rhinocerotid? tooth, × 2. From the Tejon Hills, at the southern end of the San Joaquin Valley, California.

FIG. 7. *Isurus*, near *planus* (Agassiz). Natural size. From the west side of Comanche Creek, Tejon Hills, southern end of the San Joaquin Valley, California. (Lower division?)

stylid column resembles that of *Hipparion* in being slightly wider anteroposteriorly than in any California *Merychippus* species. This type is probably specifically distinct from that represented by the lower tooth, no. 21484, found at Comanche Creek.

MERYCODUS, sp.

The distal portion of a metatarsus (fig. 4) from Mr. Pack's collection obtained in the Tejon Hills is almost identical in form and dimensions with *Merycodus* specimens from the Barstow Miocene and could not certainly be distinguished from a form found in the Ricardo beds. The Tejon Hills specimen is perhaps slightly smaller than the corresponding element in the Barstow material.

A single proximal phalanx (figs. 5*a* and 5*b*) from the Tejon Hills collections is similar to *Merycodus* phalanges from the Barstow fauna. It seems slightly more slender and smaller than the average of the *Merycodus* phalanges from the Barstow fauna, but is not shorter than the smallest. It is perhaps slightly more slender than the Ricardo specimens. The form represented by this bone may be specifically distinct from *M. necatus*, the Barstow species.

These *Merycodus* specimens evidently represent a faunal stage later than early Miocene and earlier than late Lower Pliocene.

RHINOCEROTID OR PROBOSCIDEAN TOOTH FRAGMENT

A small fragment of a large cheek-tooth (fig. 6) with thick enamel was at first considered to represent a proboscidean of the *Tetrabelodon* type. The structure of the enamel is in some respects more like that in forms of the rhinoceros group.

ISURUS, near PLANUS (Agassiz)

A well-preserved shark tooth (fig. 7) represents a form near *Isurus planus* described by Agassiz from Ocoya Creek, or Poso Creek, California. This species is also reported by Jordan[4] from the "Temblor" near Bakersfield, California.

Transmitted September 4, 1914

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[4] Jordan, David S., Univ. Calif. Publ. Bull. Dept. Geol., vol. 5, p. 107, 1907.

NEW SPECIES OF THE HIPPARION GROUP FROM THE PACIFIC COAST AND GREAT BASIN PROVINCES OF NORTH AMERICA

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Introduction

In recent studies of Tertiary faunas occurring in the region west of the Wasatch Range several species of the *Hipparion* type have appeared which seem distinct from any thus far described. As this group has considerable importance in discussion of the West American Tertiary and reference to the species is necessary in papers in which specific descriptions seem not properly included, it is deemed desirable to present a brief statement of the characters of the new forms at this time.

Neohipparion gidleyi, n. sp.

Type specimen, an upper molar three, no. 21382. Probably from a stratum just below the coal seam at a mine on the Lawler Ranch, six miles east of Petaluma, California. The formation has been doubtfully referred to the San Pablo Miocene, but may represent a later period.

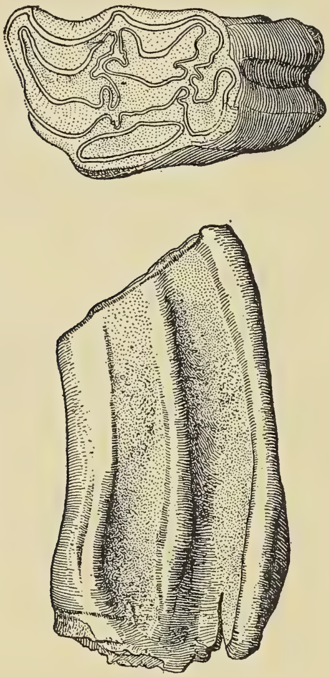
This species resembles *Neohipparion affine* in its large size and in the high degree of lateral compression of the protocone. The anterior and posterior fossettes (fig. 1) are narrow transversely and the enamel surrounding them shows comparatively few plications. *Neohipparion gidleyi* seems to be distinguished from *N. affine* by its narrow fossettes, wider protocone, and slightly larger size. The

University of California Publications, Bulletin of the Department of Geology, vol. 9, no. 1, pp. 1–8, June 29, 1915.

two species are evidently closely related and seem to represent nearly the same stage of evolution.

MEASUREMENTS OF TYPE SPECIMEN

M^3, anteroposterior diameter	26.7 mm.
M^3, greatest transverse diameter	20.6
M^3, anteroposterior diameter of protocone	18.7
M^3, greatest height of worn crown	55.5



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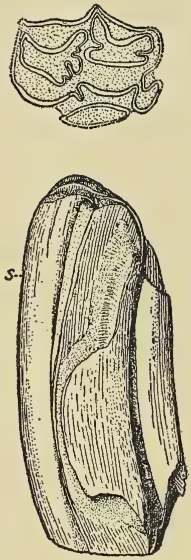

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FIG. 1. *Neohipparion gidleyi*, n. sp. M^3, no. 21382, type specimen, natural size. Outer and occlusal views. Lawler Ranch, six miles east of Petaluma, California.

FIG. 2. *Neohipparion molle*, n. sp. M^3, no. 21370, type specimen, natural size. Inner view and cross-section near base of distal third. *s*, point at which cross-section is cut. Lower Jacalitos, Pliocene, North Coalinga region, California.

NEOHIPPARION MOLLE, n. sp.

Type specimen, an upper molar, no. 21370, from the Jacalitos formation of the North Coalinga region, California. This species is characterized by length and narrowness of the upper cheek-teeth, simplicity of the enamel borders of the narrow fossettes, and unusually long anteroposterior diameter of the laterally compressed protocone.

Compared with specimens of *Hipparion mohavense* from the Ricardo Pliocene, the tooth crown in *N. molle* is smaller, the fossettes are relatively narrow, and the walls of the fossettes show less plication. The protocone of the Jacalitos species is absolutely wider anteroposteriorly and much narrower transversely.

The form represented by specimen no. 21370 (fig. 2) resembles *Neohipparion montezumae* described by Leidy from Lacaultipan, Hidalgo, Mexico, in general dimensions. In the type specimen of *N. montezumae* the borders of the fossettes are more complicated while the protocone is not as wide anteroposteriorly and is relatively less compressed laterally than in the Coalinga form. Better material of both the Mexican and the Coalinga forms may show closer relationship or even identity of the two. *N. sinclairii* of the Rattlesnake Pliocene in eastern Oregon is of the same general type as *N. montezumae* and *N. molle*.

MEASUREMENTS OF TYPE SPECIMEN

M^3, anteroposterior diameter	*a*19.3 mm.
M^3, transverse diameter	*a*15.8
M^3, anteroposterior diameter of protocone	9.4
M^3, length of crown	48

a, approximate.

NEOHIPPARION LEPTODE, n. sp.

Type specimen, a lower molar, no. 19414, Thousand Creek Beds, Thousand Creek, Nevada. Crown much elongated, slender, relatively straight, well cemented, much compressed laterally. Metaconid-metastylid column long anteroposteriorly, narrow transversely, with wide, flat internal groove. Hypoconid ridge prominent. A strong external protoconid ridge present.

Specimen 19414 (fig. 3) from locality 1101 in the Thousand Creek region resembles in many respects the peculiar *Equus eurystylus* described by Cope[1] from the Goodnight? Beds of Paloduro Cañon, Texas. Gidley[2] considers the horizon at which this fauna was found as upper Miocene. *E. eurystylus* is distinguished by extreme narrowness of the lower molar crowns, by the great anteroposterior diameter of the metaconid-metastylid column and its close appression to the protoconid and hypoconid, and by the presence of an anteroexternal ridge on the protoconid and one on the hypoconid. These characters of *E. eurystylus* appear in no. 19414 from Thousand Creek. The lower molar (M_2) from Thousand Creek is very long and narrow and was heavily cemented. The anteroexternal ridges on the protoconid and hypoconid are strongly developed, as in *E. eurystylus*. As in Cope's species, the external ridge on the hypoconid forms a prominent ridge on the middle of the external face of the crown.

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[1] Cope, E. D., Geol. Surv. Texas, 3rd Ann. Rep. for 1891, p. 43, pl. 12, figs. 7–8, pl. 20, fig. 6. Issued 1892.

[2] Gidley, J. W., Bull. Am. Mus. Nat. Hist., vol. 19, p. 632, 1903.

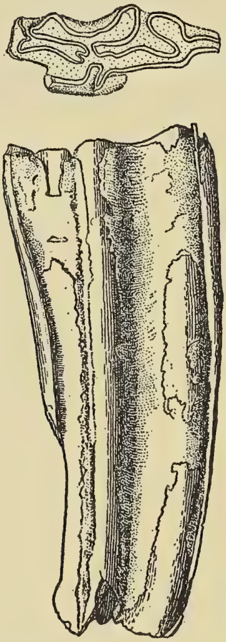

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FIG. 3. *Neohipparion leptode*, n. sp. M_2, no. 19414, type specimen, natural size. Inner and occlusal views. Thousand Creek, Pliocene, Thousand Creek, Nevada.

Gidley[3] held that Cope's *Equus eurystylus* represented the genus *Hipparion*. While it is true that the anteroexternal ridge of the protoconid and most of the other characters of *E. eurystylus* may appear in milk teeth of *Equus*, Gidley's reference of this form to a group in or near *Hipparion* is well supported.

Specimen no. 19414 from Thousand Creek represents a species in many respects near *Neohipparion eurystyle?* (Cope). The Thousand Creek form is larger and the details of structure are sufficiently different to separate the two, at least tentatively. It also resembles other American forms of the *Hipparion* group, as *Neohipparion occidentale,* in many characters, but seems not clearly referable to these species. The writer has, therefore, referred the Thousand Creek form tentatively to a distinct species.

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[3] Gidley, J. W., Bull. Am. Mus. Nat. Hist., vol. 14, p. 126, 1901.

MEASUREMENTS

	N. leptode, No. 19414	N. eurystyle
M_2, greatest anteroposterior diameter	29+ mm.	24
M_2, transverse diameter	11	10
M_2, greatest length of crown	66	55
M_2, anteroposterior diameter of metaconid-metastylid column	14.6	13

An upper molar[4] (no. 12581) from the same locality as the lower molar no. 19414 presumably belongs also in or near the *Hipparion* group. This tooth is long and nearly straight. The outer styles are well developed. The mesostyle is of almost even width throughout its whole length. The fossettes are unusually narrow transversely and show a few strong plications. The inner side of the tooth is broken away and it is not possible to determine the characters of the protocone.

MEASUREMENTS OF No. 12581

M^1, anteroposterior diameter near base	21.7 mm.
M^1, length of slightly worn crown	65.8

HIPPARION PLATYSTYLE, n. sp.

Neohipparion, sp. Merriam, J. C., Univ. Calif. Publ., Bull. Dept. Geol., vol. 7, p. 375, figs. 1*a* to 1*c*, 1913.

Type specimen no. 19830, a second upper premolar from the Orinda Pliocene southwest of Mount Diablo, California.

A single tooth obtained from the Orinda beds represents a member of the *Hipparion* group not clearly identical with any known form. The crown is large and well cemented. Though somewhat worn, the form of the fossettes suggests that the crown was never greatly elongated. The small protocone pillar is distinct and is flattened laterally. The fossettes are slightly narrower than in *Hipparion mohavense.* Their enamel walls are moderately crinkled. The outer styles are heavy.

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[4] See Merriam, J. C., Fauna of Virgin Valley and Thousand Creek, Univ. Calif. Publ. Bull. Dept. Geol., vol. 6, p. 263, figs. 32*a* and 32*b*, 1911.

This species most nearly approaches the *Hipparion* forms of the Ricardo fauna. It differs from *H. mohavense* in its more strongly flattened protocone and transversely narrower fossettes. The characters of a single specimen (no. 19478) from the Ricardo fauna approach those of the Orinda specimen, but are not sufficiently near to warrant the conclusion that the two are specifically identical.

MEASUREMENTS OF TYPE SPECIMEN

P^2, greatest anteroposterior diameter	25.8 mm.
P^2, greatest transverse diameter	21.6
P^2, anteroposterior diameter of protocone	8.2

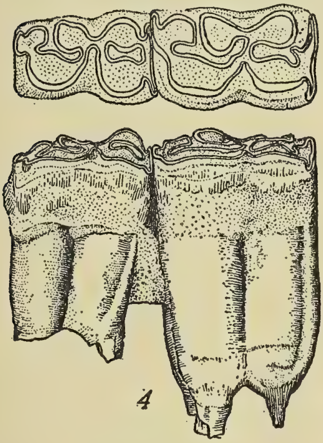
HIPPARION CONDONI, n. sp.

In the collections of Professor Thomas Condon, formerly of the University of Oregon, there are two specimens representing a protohippine horse of *Hipparion* type obtained from sedimentary deposits of eastern Washington. The Ellensburg formation, in which these remains were found, has generally been considered as Miocene on the basis of its flora and is commonly correlated with the middle Miocene Mascall formation of the John Day basin in eastern Oregon. The material obtained by Professor Condon is of unusual interest, as it represents the only available mammalian remains from the Ellensburg beds.

Of the two specimens from Ellensburg one (fig. 4) consists of two lower cheek-teeth (no. 672, Univ. Oregon), the other is the anterior portion of a lower jaw with five incisors (fig. 5) (no. 668, Univ. Oregon). Both specimens are partly covered with a matrix consisting of moderately coarse, gray sandstone. It is to be presumed that both specimens are from the same locality.

The lower cheek-teeth represent P_4 and M_1. The teeth are hypsodont, but appear to be considerably worn. In their present stage of wear, they are not longer than the crowns of some of the advanced *Merychippus* forms from the late Miocene. In an unworn state they may have attained a length considerably greater than that normal in *Merychippus.* Both crowns are heavily cemented at the summit.

The metaconid-metastylid column is longer anteroposteriorly than in any *Merychippus* form known to the writer and corresponds in this diameter to the dimensions of the column in species of the *Hipparion* group. The groove between metaconid and metastylid is wide and flat as in *Hipparion*, rather than narrow and sharp as is commonly the case in *Merychippus*. The parastylid extends inward as far as the inner border of the metaconid. A sharp anteroexternal ridge is developed on the protoconid. The valleys anterior and posterior to the metaconid-metastylid column are comparatively narrow transversely, owing to the large size of the metaconid and metastylid. These valleys correspond approximately in size to those commonly seen in *Hipparion*, and are narrower than those in most species of *Merychippus*. The entoconid is large and unusually full on the anterointernal side. In *Merychippus* this region of the entoconid is commonly not as well developed and may be truncated obliquely. In *Hipparion* this region of the entoconid is commonly full and the anterointernal angle is nearly a right angle, as in the Ellensburg specimen.



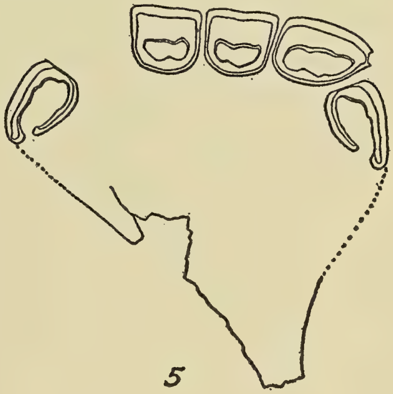


FIG. 4. *Hipparion condoni*, n. sp. P_4 and M_1, no. 672, Univ. Oreg. Col. Type specimen, natural size. Outer and occlusal views. Ellensburg, Washington.

FIG. 5. *Hipparion condoni?* n. sp. Lower incisors, no. 668, Univ. Oreg. Col. Natural size. Ellensburg, Washington.

The fragment representing the symphysial region of the lower jaw with the incisor teeth (no. 668, Univ. Oregon) is from an animal not differing greatly in dimensions from a number of *Merychippus* specimens from the Upper Miocene of the Barstow region. The incisors are considerably worn, but still show the inner enamel rings of the pits. No satisfactory material representing this portion of the adult dentition of *Merychippus* from the Mascall Miocene is available for a comparison. The teeth are in general larger than those of *Merychippus calamarius* of the Barstow Miocene and are much smaller than incisors of a large *Hipparion* from Ricardo. On the somewhat worn crowns shown in figure 5 the enamel invaginations are clearly shown on all three teeth. The incisors were evidently deeply cupped, but this condition obtains also in the incisors of *Merychippus,* although the infolding of the enamel on the third lower incisor of *Merychippus* is much less strongly marked than on the Ellensburg specimen.

The stage of advance shown by the cheek-teeth of the Ellensburg specimen seems to the writer to be that of *Hipparion* rather than that of *Merychippus.* The form represented in no. 672 does not correspond exactly to any species known to the writer and may be designated as a new species, *Hipparion condoni.* It is distinguished by the size of the crown and by the size and form of the metaconid-metastylid column. *Hipparion mohavense* of the Ricardo Pliocene seems to be the nearest form among the species west of the Wasatch. The Ellensburg species seems to differ from *H. mohavense* in flatness of the outer walls of the protoconid and hypoconid and in the greater prominence of the anteroexternal angle of the protoconid. Both of these characters may be due to combination of age and individual characters. The habit of the teeth in the Ellensburg specimen suggests that additional material will show more rather than fewer differences separating this form from the *H. mohavense.* *Neohipparion leptode* of the Thousand Creek Pliocene and an allied form from the Rattlesnake Pliocene differ from the Ellensburg specimen in the presence of a very strong anteroexternal ridge on the hypoconid.

Although *Hipparion* has been listed as occurring in the Mascall, Middle Miocene, the writer knows of no occurrence that can certainly be stated to be located within the limits of that formation. Unless it be true that *Hipparion* actually occurs in the Mascall, it seems that the Ellensburg formation may be of considerably later date than the beds containing the typical Mascall fauna of the John Day Valley in eastern Oregon.

MEASUREMENTS

	Hipparion condoni, Ellensburg No. 672 U.O.	Merychippus, Barstow No. 21459	Hipparion mohavense, Ricardo No. 19785
P_4, anteroposterior diameter	21 mm.	24.7	23.8
P_4, transverse diameter across protoconid	11.1	12	11.9
P_4, anteroposterior diameter of metaconid-metastylid column	12.6	9.1	14.7
P_4, height of worn crown	31	44	32
M_1, anteroposterior diameter	17.6	25.4	....
M_1, transverse diameter across protoconid	10.3	10.1	....
M_1, anteroposterior diameter of metaconid-metastylid column	11.2	9.9	....
	Hipparion, Ellensburg, No. 668 U.O.	Merychippus, Barstow No. 21776	
I_1, anteroposterior diameter	8.3	7.7	....
I_1, transverse diameter	9.3	....	....
I_2, anteroposterior diameter	8.3	7.7	....
I_2, transverse diameter	12.1	6.5	....
I_3, anteroposterior diameter	7.4	5.7	....
I_3, transverse diameter	12	5.9	....

Transmitted June 7, 1915

MAMMALIAN REMAINS FROM THE CHANAC FORMATION OF THE TEJON HILLS, CALIFORNIA

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Introduction

Within a few weeks following the publication of a note[1] on mammalian remains from the Tejon Hills of California, in 1915, a party representing the Department of Palaeontology of the University of California visited the Tejon Hills, at the request of the writer, to secure additional material, and to make further study of the occurrence of the fauna. This party, consisting of J. P. Buwalda, B. L. Clark, and F. E. Vaughan, examined the Tejon Hills area in which the first material was found and re-studied with care the beds from which R. W. Pack of the United States Geological Survey, and later R. H. Stoner of the University of California, secured the interesting mammalian remains described in 1915.

For important mammalian material secured, and for additional data concerning the sequence of formations and occurrence of mam-

University of California Publications, Bulletin of the Department of Geology, vol. 10, no. 8, pp. 111–127, December 23, 1916.

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[1] Merriam, J. C., Remains of land mammals from marine Tertiary beds in the Tejon Hills, California, Univ. Calif. Publ., Bull. Dept. Geol., vol. 8, pp. 283–288, 1915.

malian remains, the writer is much indebted to the party visiting the Tejon Hills area in 1915. Reports on the geologic occurrence furnished by members of the 1915 party are given in full in the discussion of stratigraphic position following.

Stratigraphic Position of Mammal-bearing Chanac Formation in the Tejon Hills

As noted in the earlier publication[2] on the Tejon Hills fauna, difference of opinion has existed concerning the formation sequence and the age of the deposits containing mammalian remains obtained in this area. The geologic section has not been easily understood, and age determination could not readily be made without fuller information as to invertebrate faunal sequence of the Pacific Coast province than was at hand at the time of the first examination of the Tejon Hills region. In the earlier studies there seemed good reason for considering that remains of land mammals were found in strata containing a marine invertebrate fauna comparable to that of beds of the Temblor Range referred to Lower Miocene. Other opinion suggested tentatively the "Santa Margarita" or late Miocene age of the mammal-bearing formation.

With the evidence available at the time of publication of the earlier paper[3] the writer concluded that intensive study of the invertebrate fauna of the Tejon Hills would be necessary before a fully satisfactory correlation with other marine Tertiary formations of the San Joaquin Valley could be made, and expressed the view that faunas of both "Santa Margarita" and "Temblor" stages might be represented in the section.

As is stated in the reports by Dr. Buwalda and Dr. Clark given below, the work of the 1915 party points toward the existence of three divisions or three formations in the geologic section of the Tejon Hills. The divisions reported are: (1) marine "Temblor" or Monterey, generally considered as Lower Miocene; (2) marine "Santa Margarita," considered as Upper Miocene; and (3) an alluvial or fresh-water formation described as the "Chanac" by Dr. Buwalda. An unconformity is reported to occur between "Temblor" and "Santa Margarita." The Chanac formation is later than the "Santa Margarita" and is presumed to be unconformable upon it, but the evidence is not complete on this point.

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[2] Merriam, J. C., *op. cit.*, 1915.

[3] Merriam, J. C., *op. cit.*, pp. 284 and 285, 1915.

The 1915 party found remains only in beds of the uppermost or Chanac formation, though they occurred at localities in close proximity to marine beds.

Following are the statements as to geologic sequence and occurrence of mammalian fauna by Dr. Buwalda and Dr. Clark:

Note on the Geology of the Tejon Hills, Furnished by J. P. Buwalda

The Tejon Hills occupy an area about seven miles long in a north-south direction and about three miles wide, on the eastern side of the southern end of the San Joaquin Valley. They rise to heights of six hundred to eight hundred feet above the floor of the valley, and present a subdued topography

The section in the Tejon Hills contains three Tertiary formations. The lowermost is a series of sandstones and conglomerates considered by Dr. B. L. Clark to be of Monterey age (Vaqueros or Temblor, marine Lower Miocene). Overlying these strata unconformably is a formation considered by Dr. Clark to be the equivalent of the "Santa Margarita" (marine Upper Miocene). The uppermost formation is a terrane which is apparently of terrestrial origin.

The Monterey is exposed over an area about two and one-half miles in length between Comanche Creek and the escarpment of old crystalline rocks of the Sierra Nevada. It lies on an eroded surface of the crystalline rocks and is not faulted against them. The formation consists of dark gray and yellow sandstones. It is often conglomeratic, and is usually rather coarse and massive. Conglomerate beds occur especially in the upper and lower parts of the formation. The pebbles and boulders are usually quartz and are well waterworn. The thickness is estimated at about three hundred feet. The formation dips gently toward the west and away from the crystalline rocks. It contains a marine fauna determined by Dr. B. L. Clark as Lower Miocene.

In the northern end of the Tejon Hills, strata of distinctly different character overlie the Monterey just described and extend up on the crystalline rocks. They are exposed over an irregular area about two miles in diameter around the lower portion of Comanche Creek. These beds consist of strikingly white and cream-colored quartzose sandstones and gravels, and clay strata. The sandstones are coarse and the grains exhibit markedly the effects of water wear. The conglomerate pebbles and boulders are well rounded and polished. The formation has a thickness of perhaps one hundred feet. These beds lie with marked unconformity upon the Monterey and contain a marine fauna determined by Dr. Clark to be the "Santa Margarita" stage of the upper Miocene. At the northern end of the area these beds have been more sharply deformed than the Monterey where it is known in this area, so that they dip away from the crystalline rocks at angles of 25 degrees or more.

The uppermost stratigraphic member in the Tejon Hills extends from the northwest end of the hills over almost the entire remaining territory excepting a small area of crystalline rocks exposed at the point where Tejon Creek enters the hills, and along Chanac Creek. Areally this uppermost member is the most important terrane of the Tejon Hills. In view of their distinctiveness in lithologic character and in mode of origin the name Chanac formation is proposed for these strata. Lithologically this formation consists of angular sands and coarser angular materials. The particles are mainly rhyolitic and display white, yellow and striking reddish-brown colors in exposures. The materials are not well classified as to size and are not sharply bedded. Their characters are altogether those of a terrestrial deposit of the alluvial fan type, and they should be termed fanglomerates. Their thickness is estimated to be four hundred to six hundred feet. The Chanac fanglomerates rest upon both of the older Tertiary formations and in the southern part of the Tejon Hills upon the old crystalline rocks. From the geologic evidence it seems probable that they bear an unconformable relation to the beds they overlie, but the evidence does not appear conclusive. The distinctly different character of the materials and of the faunas of the Chanac, contrasted with the underlying formations, indicates a change from marine conditions to the terrestrial conditions, and favors the view of unconformity. Theoretically, such changes might be the result of the filling of a marine basin and the deposition, without interruption, of terrestrial beds upon the marine strata. The areal relations, however, suggest unconformity, although no discordance was observed in the attitude of the strata of the Chanac and "Santa Margarita," and no pre-Chanac surface of erosion.

Note on the Marine Tertiary Faunas of the Tejon Hills Section, Furnished by B. L. Clark

Marine deposits of the two stages of the Miocene are represented in the Tejon Hills. A number of characteristic species of that phase of the Miocene generally known as the Monterey of the local phase designated as Vaqueros or Temblor are represented in gray and brown sandstone, having a thickness of about 300 feet. These beds rest unconformably upon the granite and have a dip of from 10 degrees to 15 degrees. Certain of the species found in this formation are generally considered characteristic fossils of the Monterey group. Among these forms may be listed the following:

Scutella andersoni Twitchell
Scutella merriami Anderson
Pecten andersoni Arnold
Leda ochsneri Anderson and Martin
Oliva californica Anderson
Trophon kernensis Anderson
Conus oweniana Anderson
Terebra cooperi Anderson
Turritella ocoyana Conrad

Disconformably overlying the Vaqueros or Temblor of the Tejon Hills is the Santa Margarita Upper Miocene. The beds of this formation are best exposed near the mouth of Comanche Creek. Here they have a thickness of between 50 and 100 feet. They are generally composed of light-colored arkose sandstones with which occur lenses of clay and gravel. The fauna found in these beds apparently belongs to the Astrodapsis whitneyi zone as recognized in the San Pablo group of the Mount Diablo region, and to the same horizon as the Santa Margarita beds to the north of Coalinga. The following species were collected from the Santa Margarita of the Tejon Hills on the west side of Comanche Creek near the western boundary of the NW ¼, sec. 13, T 32 S, R 29 E, M. D. B. and M.

Dosinia arnoldi Clark
Metis alta (Conrad)
Ostrea titan Conrad
Ostrea, cf. vespertina Conrad
Pecten crassicardo Conrad
Pecten crassicardo, n. var.
Pecten hastatus Sowerby
Pecten raymondi Clark
Phacoides richthofeni (Gabb)
Phacoides sanctaecrucis Arnold
Pinna alamedensis Yates
Piteria stalderi Clark
Saxidomus nuttali Conrad
Siliqua, cf. lucida (Conrad)
Venus pertenuis Gabb
Bulla, sp.
Calyptraea, sp.
Conus, sp.
Fusinus, n. sp.
Nassa pabloensis Clark
Natica, sp.
Shark teeth

Composition and Relationships of Mammalian Fauna of the Chanac Formation

The representation of mammalian forms obtained in the land-laid beds of the Chanac formation is very scanty, but it includes more and better preserved material than that upon which the first note was based. Following is a list of the forms now available:

Rhinocerotid, indet.
Protohippus tehonensis Merriam.
Neohipparion gratum tehonense Merriam.
Neohipparion, near molle Merriam.
Prosthennops, sp.
Camelid, indet. large.
Merycodus, near necatus Leidy.
Proboscidean (Tetrabelodon?), indet.

The general aspect of the small assemblage of forms now known is not materially different from that originally suggested. It is clear, however, that the most commonly encountered horses of this fauna represent the genus *Hipparion*. The best-known teeth are those of two small forms, *Neohipparion gratum tehonense*, closely resembling *Neohipparion gratum* of the Great Plains region; and a form closely approaching *Neohipparion molle* found in the lower portion of the Jacalitos-Etchegoin Pliocene section of the North Coalinga region. Horses closely resembling those of the Tejon Hills region have been found by R. W. Pack in late Tertiary beds on the eastern flank of the Mount Diablo Range, southwest of Modesto. Of the Hipparion-like horses known in the faunas of the Mohave Desert region, the type most closely approaching the Tejon Hills form is found in an undescribed species obtained in the upper portion of the Ricardo Pliocene section. The Ricardo form does not, however, seem to be specifically identical with that from the Tejon Hills. The Tejon Hills horse described as *Protohippus tehonensis* has some resemblance to a form found in the upper Miocene Barstow formation of the Mohave Desert, but seems not to be specifically identical with the Barstow form. The Tejon Hills *Protohippus* also shows similarity to a species known in the lower portion of the Jacalitos-Etchegoin section of the North Coalinga region.

The rhinocerotid and mastodontine remains from the Tejon Hills furnish no definite evidence as to age. Rhinoceroses are well represented in the Thousand Creek and Rattlesnake Pliocene of Nevada and Oregon, and are known in the Pliocene of the Pinole Tuff type section in San Francisco Bay region of California. It is interesting to note that as yet no remains of rhinoceroses have been secured from any of the four Cenozoic faunas of the Mohave Desert. It is possible that they are present in both the Barstow and Ricardo, but have not been recognized. Abundant material is, however, available from both Barstow and Ricardo with no recognized remains of rhinoceroses, while both of the exceedingly scanty collections from the Tejon Hills have included fragments of rhinoceros teeth. The rhinoceros group possibly avoided the peculiar habitat of the Mohave Desert, and may have existed in the California province west of the main divide during the period in which Miocene and Pliocene formations were being deposited in the Mohave area.

The *Merycodus* and camel remains of the Chanac fauna are not sufficiently characteristic to give us a determination of the relationship of the Tejon Hills assemblage to that of the Barstow and Ricardo. The single *Merycodus* tooth is very close in its form and dimensions to teeth from the Ricardo, and may represent the same species. The *Merycodus* horn fragments are not to be distinguished from types represented in both the Barstow and Ricardo faunas.

The available evidence furnished by the Chanac mammalian fauna indicates that it represents a stage older than the Pliohippus proversus zone of the Upper Etchegoin in the North Coalinga region, and later than the Barstow, the youngest recognized Upper Miocene of the Pacific Coast and the Great Basin provinces. The Chanac is evidently of an early Pliocene or latest Miocene phase. It is presumably nearest to the faunas of the lower portion of the Jacalitos-Etchegoin of the North Coalinga region and to the Ricardo stage of the Mohave area.

Description of Chanac Mammalian Fauna

RHINOCEROTID AND MASTODONTINE REMAINS

In the earlier discussion of the Tejon Hills fauna a fragment of a large tooth,[4] at first assumed to represent a proboscidean, was tentatively considered as a member of the Rhinocerotidae, as the structure of the outer wall closely resembled that of rhinoceros tooth forms. In the collection obtained in 1915 a portion of a large rhinoceros lower cheek-tooth furnishes satisfactory evidence of the presence of this group in the Chanac fauna. This tooth fragment, no. 22368, represents a large animal of uncertain systematic position. The presence of a rhinoceros in the Tejon Hills fauna is a matter of considerable interest, as no remains representing the Rhinocerotidae have been recognized in either the Barstow or the Ricardo fauna. A calcaneum representing a member of this group is known in the fauna of the Pinole Tuff Pliocene of middle California, and the group has been reported from the Thousand Creek and Rattlesnake Pliocene of northern Nevada and Oregon. It is possible that in late Tertiary time this group did not range into the Mohave Desert area.

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[4] Merriam, J. C., *op. cit.*, fig. 6, 1915.

NEOHIPPARION GRATUM TEHONENSE, n. subsp.

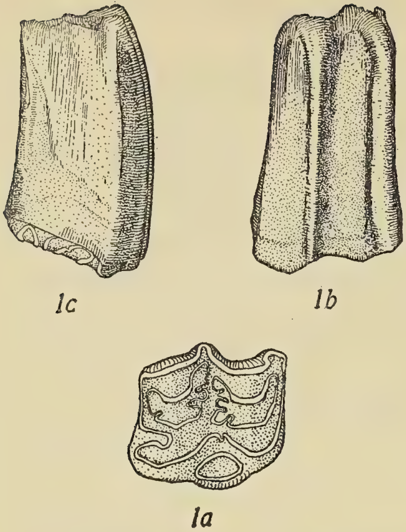
Type specimen, no. 21780, from the Chanac formation of the Tejon Hills at the southern end of the San Joaquin Valley, California.

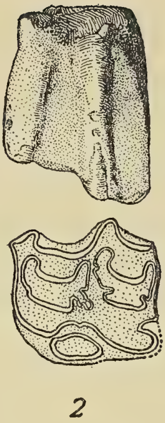
This species corresponds approximately in size and form to *Neohipparion gratum* of the Great Plains region. It is doubtfully distinguished from the typical form of that species by the tendency to show a more nearly circular cross-section of the protocone and by somewhat dubious characters in width of crown and nature of the enamel folds bordering the fossettes.

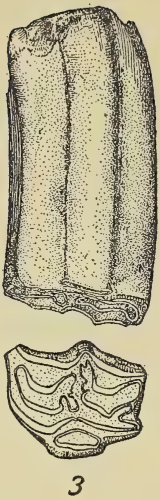
The character of the protocone of the Chanac form (figs. 1*a* to 1*c*) suggests *Hipparion plicatile* of the Alachua clays of Florida, but the crowns in that species seem larger and relatively wider than in the Chanac species. *H. ingenuum* also of the Alachua clays is not widely removed from the Chanac species, but the protocone is smaller. The Chanac species differs from *Neohipparion montezumae* in its more nearly circular section of protocone and possibly in a tendency to relatively greater transverse diameter of the fossettes.

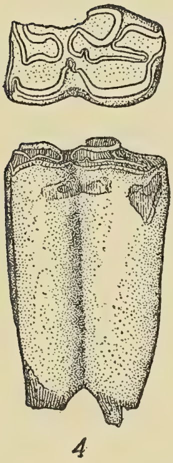
The characters of the Chanac species represented by specimen 21780 are in general like those of *Hipparion mohavense* of the Ricardo Pliocene, but they are shown in a form with smaller dimensions, and approaching the combination of characters of *N. gratum*. The species is evidently very near the Great Plains form of *N. gratum*, and it is not impossible that larger collections will exhibit a range of characters making even subspecific separation inadvisable.

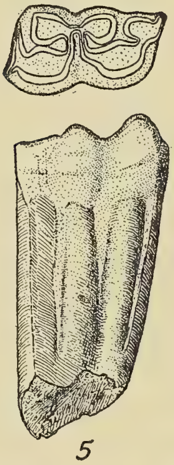
An upper molar (figs. 8*a* to 8*c*) obtained by R. W. Pack of the United States Geological Survey on the north side of Hospital Creek (SE corner sec. 11, T 4 S, R 5 E) is similar to *N. g. tehonense* in dimensions. In this specimen the protocone is very small and approximately circular in cross-section.

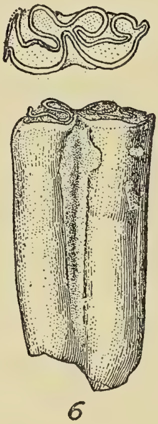












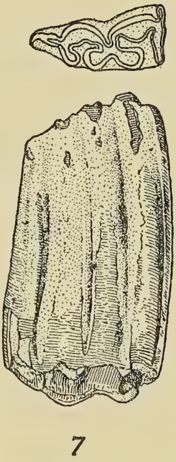


FIG. 1. *Neohipparion gratum tehonense* Merriam. M$\underline{1}$?, type specimen, no. 21780, natural size. Fig. 1*a*, occlusal view; fig. 1*b*, outer view; fig. 1*c*, posterior view. Chanac formation, southern end of San Joaquin Valley, California.

FIG. 2. *Neohipparion gratum tehonense* Merriam. P$\underline{4}$, no. 21782, natural size. Chanac formation, southern end of San Joaquin Valley, California.

FIG. 3. *Neohipparion*, near *molle* Merriam. M$\underline{2}$, no. 21781, natural size. Chanac formation, southern end of San Joaquin Valley, California.

FIG. 4. *Neohipparion gratum tehonense* Merriam. P$\overline{4}$, no. 21784, natural size. Chanac formation, southern end of San Joaquin Valley, California.

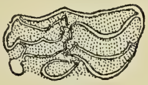
FIG. 5. *Neohipparion gratum tehonense* Merriam. M$\overline{2}$, no. 21785, natural size. Chanac formation, southern end of San Joaquin Valley, California.

FIG. 6. *Neohipparion*, near *gratum tehonense* Merriam. M$\overline{2}$?, no. 22364, natural size. Chanac formation, southern end of San Joaquin Valley, California.

FIG. 7. *Neohipparion*, near *gratum tehonense* Merriam. M$\overline{3}$, no. 21786, natural size. Chanac formation, southern end of San Joaquin Valley, California.

An upper cheek-tooth figured in the earlier paper on the Tejon Hills fauna[5] may represent *N. g. tehonense*, or is possibly a more primitive form.

A single fragmentary upper cheek-tooth (no. 1323) from beds presumed to belong to the Orinda Pliocene near Bolinger Canyon, California, shows the approximate form and dimensions of upper cheek-tooth of *N. g. tehonense* from the Tejon Hills. This specimen has been referred to as representing a Hipparion-like type distinct from two larger forms known from the Orinda.[6] It is possible that specimen 1323 represents a species in or near *N. g. tehonense*.



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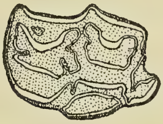

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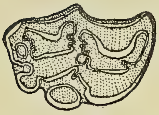

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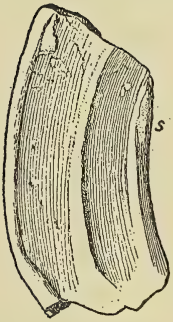

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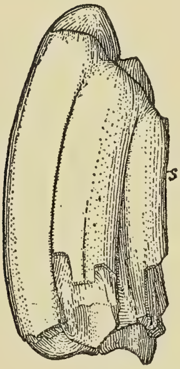

9a

Figs. 8*a*, 8*b*, and 8*c*. *Neohipparion*, near *gratum tehonense* Merriam. M$\underline{3}$, natural size. Outer and occlusal views, and section at *s* near proximal end of distal third. Fig. 8*a*, outer view; fig. 8*b*, cross-section at *s*; fig. 8*c*, occlusal view of slightly worn tooth. Collected by R. W. Pack, of U. S. Geol. Survey, north side of Hospital Creek, western border of San Joaquin Valley, California, at S.E. corner sec. 11, T 4 S, R 5 E, M. D. B. & M.

Figs. 9*a* and 9*b*. *Neohipparion*, near *molle* Merriam. M$\underline{3}$, natural size. Fig. 9*a*, inner view; 9*b*, section at *s* near proximal end of distal third. Collected by R. W. Pack, of U. S. Geol. Survey, one mile north of Ingram Creek, western border of San Joaquin Valley, California.

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[5] Merriam, J. C., *op. cit.*, p. 286, fig. 1, 1915.

[6] Merriam, J. C., Univ. Calif. Publ., Bull. Dept. Geol., vol. 7, p. 376, fig. 2, 1913.

Several lower cheek-teeth from the Chanac formation of the Tejon Hills represent small *Hipparion* forms. It is possible that more than one species is present. If so the larger teeth as no. 21784 and 21785 (figs. 4 and 5) presumably represent *N. g. tehonense*, and the smaller specimens, as no. 22364 (fig. 6), might belong with the narrower upper cheek-teeth approaching *Neohipparion molle*. The small lower cheek-teeth from the Chanac formation approach the characters of a small Hipparion specimen (no. 22387) from the Ricardo beds above the uppermost basalt in the type section.

A lower cheek-tooth figured in the first discussion of the Tejon Hills fauna[7] corresponds to the smaller of these two faunas.

NEOHIPPARION, near MOLLE Merriam

A second upper molar, no. 21781 (fig. 3) from the Tejon Hills shows a much narrower crown, narrower fossettes and a flatter protocone than the specimen distinguished as *Neohipparion gratum tehonense*. In width of crown and narrowness of fossettes this specimen approaches *Neohipparion molle*[8] of the North Coalinga Jacalitos-Etchegoin section, but the protocone is narrower anteroposteriorly. In character of protocone no. 21781 is intermediate between *N. molle* and *N. g. tehonense*.

A M$\underline{3}$ (figs. 9*a* and 9*b*) evidently representing *Neohipparion molle*, obtained by R. W. Pack of the Geological Survey from beds overlying strata referred to the San Pablo, one mile north of Ingram Creek, on the east flank of the foothills of the Mount Diablo Range, shows the protocone a little narrower anteroposteriorly than in the type of *N. molle*. As the type of *N. molle* and the specimen found by Mr. Pack both represent M$\underline{3}$, it is possible that since the Tejon Hills specimen no. 21781 is a M$\underline{2}$ it may also belong in *N. molle*, as the protocone of M$\underline{2}$ is commonly shorter anteroposteriorly than in M$\underline{3}$.

A M$\underline{3}$ (figs. 8*a* to 8*c*) obtained by Mr. Pack from beds overlying strata referred to San Pablo on the north side of Hospital Creek in the foothills of the Mount Diablo Range southwest of Modesto shows much the same width of crown and narrowness of fossettes as in M$\underline{3}$ obtained by Mr. Pack at Ingram Creek several miles to the southeast, but the protocone is small and almost circular in cross-section. If this specimen by any chance is shown to represent the same form as the M$\underline{3}$ from Ingram Creek there might be reason for considering the possible identity of *N. molle* and the *N. gratum* group. For the present there seems good reason for keeping the forms with wide protocone separate from the group with narrow protocone.

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[7] Merriam, J. C., Univ. Calif. Publ., Bull. Dept. Geol., vol. 8, p. 286.

[8] See Merriam, J. C., Univ. Calif. Publ., Bull. Dept. Geol., vol. 9, p. 3 and fig. 2, 1915.

Measurements

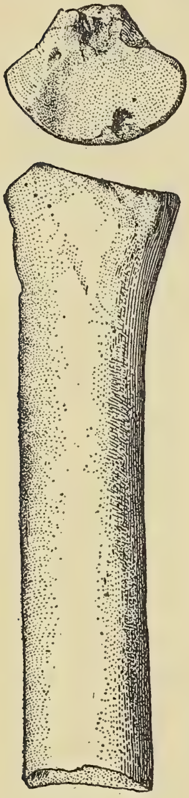
	No. 21780
M$\underline{1}$?, anteroposterior diameter	19.1 mm.
M$\underline{1}$?, transverse diameter	17.7
M$\underline{1}$?, anteroposterior diameter of protocone	6.4
	No. 21781
M$\underline{2}$, anteroposterior diameter	17.8 mm.
M$\underline{2}$, transverse diameter at middle height of crown	*a*16.5
M$\underline{2}$, anteroposterior diameter of protocone	6.1
	No. 21782
P$\underline{4}$, anteroposterior diameter	18.8 mm.
P$\underline{4}$, transverse diameter	18.0
P$\underline{4}$, anteroposterior diameter of protocone	6.6
	No. 21784
P$\overline{4}$, anteroposterior diameter	20.3 mm.
P$\overline{4}$, transverse diameter	*a*11.1
P$\overline{4}$, anteroposterior diameter of metaconid-metastylid column	12.9
	No. 21785
M$\overline{2}$, anteroposterior diameter	19.3 mm.
M$\overline{2}$, transverse diameter	9.5
M$\overline{2}$, anteroposterior diameter of metaconid-metastylid column	11.3

a, approximate.

LIMB FRAGMENTS OF NEOHIPPARION

Two fragments of small metapodials represent an equid form not larger than the smallest species of *Merychippus* of the Barstow Miocene. Specimen 22365 (fig. 10), the proximal end of a small slender metacarpal three, possesses a narrow shaft suggesting that of the small Barstow *Merychippus*. The position of the unciform facet is, however, quite different from that in all of the many Barstow specimens examined by the writer. In the Barstow forms the unciform facet cuts that of the magnum at an angle ranging between 112 and 121.5 degrees. In the Ricardo horses, so far as known, the corresponding angle ranges between 128 and 131 degrees, and the unciform facet approaches distinctly nearer to the plane of the magnum facet than in the Barstow forms. In no. 22365 from the Tejon Hills the magnum-unciform angle is 131 degrees, as in the Ricardo horses.

A second metapodial specimen, no. 22376 (fig. 11) represents the distal end of a small metapodial of approximately the size shown in no. 22365. In this specimen the median keel is strongly developed on the posterior side but, as in the small Barstow *Merychippus*, it tends to fade out in the proximal region of the anterior side. In the Ricardo horses the keel is more strongly expressed.



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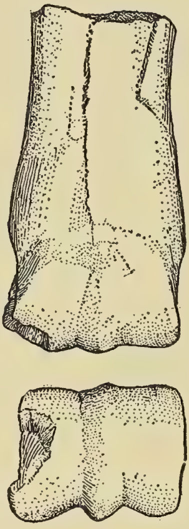

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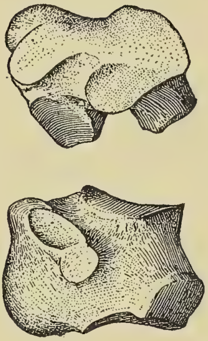

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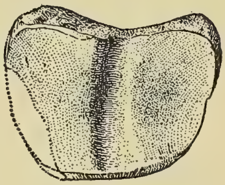

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Fig. 10. *Neohipparion*, sp. Proximal end of metacarpal 3, natural size, anterior and proximal views, no. 22365. Chanac formation, southern end of San Joaquin Valley, California.

Fig. 11. *Neohipparion* or *Merychippus*. Distal end of metapodial, no. 22376, natural size. Chanac formation, southern end of San Joaquin Valley, California.

Fig. 12. *Neohipparion* or *Merychippus*. Cuboid, no. 21787, proximal and inner view, natural size. Chanac formation, southern end of San Joaquin Valley, California.

Fig. 13. *Neohipparion* or *Merychippus*. Proximal end of first phalanx, no. 22375, natural size. Chanac formation, southern end of San Joaquin Valley, California.

In a fragmentary specimen representing a proximal phalanx, no. 22375 (fig. 13), the groove for reception of the distal keel of the metapodial is well marked at the anterior side, showing that the metapodial keel was well expressed as in the *Hipparion* type. The phalanx represents an animal of somewhat larger size than the individuals from which the small metapodial specimens have been derived.

A small cuboid, no. 21787 (fig. 12), from locality 2751, has approximately the size of the corresponding element in small *Merychippus* specimens from the Barstow Miocene. It differs from Barstow specimens in its slightly less prominent tuberosity, and in the situation of the posterior facet for the navicular somewhat nearer the proximal end of the element. In these particulars the Tejon Hills specimen approaches more closely the characters of an equid cuboid from the Ricardo Pliocene.

At locality 2751, in which the small equid metapodials, the phalanx, and the cuboid were found, no *Merychippus* teeth are known, but a number of *Neohipparion* teeth occurring there show dimensions not greater than those of the smallest *Merychippus* forms of the Barstow. It is therefore possible that the Merychippus-like limb elements represent the little *Neohipparion* species, in which resemblance to *Merychippus* is especially strong because small size has made unnecessary certain peculiar specializations in structure found in the larger and perhaps more nearly typical species of the genus.

PROTOHIPPUS TEHONENSIS Merriam

P. tehonensis Merriam, Univ. Calif. Publ. Bull. Dept. Geol., vol. 9, p. 52, figs. 4*a* and 4*b* and 4*c*, 1915.

This species is represented by a single upper molar, no. 21779, the type specimen of the species (figs. 14*a* to 14*c*), found at locality 2751 in the Chanac formation of the Tejon Hills at the southern end of the Great Valley of California.

The West-American types to which *Protohippus tehonensis* shows closest resemblances are a form referred to *Pliohippus* or *Protohippus* from the lower portion of the Jacalitos-Etchegoin section of the North Coalinga[9] region, and a species near *Protohippus* represented by specimen 21423 from the Barstow Upper Miocene of the Mohave Desert. No teeth from the North Coalinga form have yet been obtained which correspond in position in the jaw to the type of *P. tehonensis*, so that a close comparison is not possible. The Bar-

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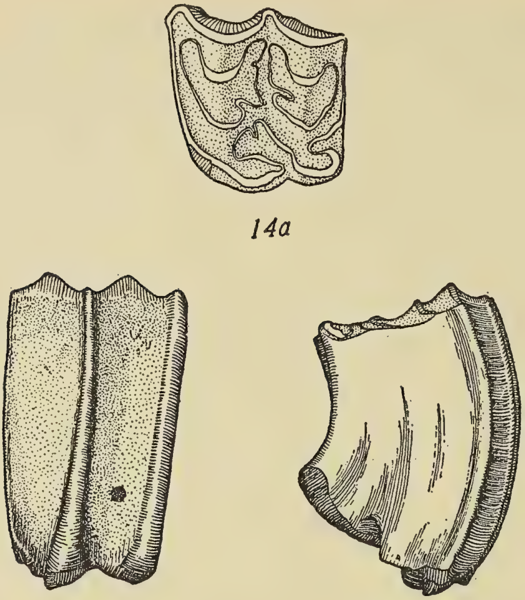
[9] See Merriam, J. C., Tertiary Vertebrate Faunas of the North Coalinga Region, Trans. Amer. Phil. Soc. N. S., vol. 22, part 3, p. 27, figs. 28*a* and 28*b*, 1915.



Figs. 14*a* and 14*c*. *Protohippus tehonensis* Merriam. M$\underline{1}$?, type specimen, no. 21779, natural size. Fig. 14*a*, occlusal view; fig. 14*b*, outer view; fig. 14*c*, posterior view. Chanac formation, southern end of San Joaquin Valley, California.

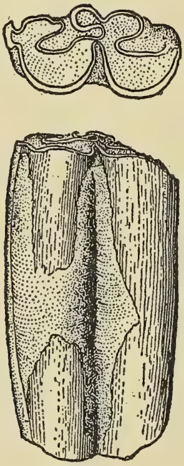


Fig. 15. *Protohippus* or *Merychippus*. P$\overline{4}$?, outer and occlusal views, no. 21484, natural size. Chanac formation, Comanche Creek, southern end of the San Joaquin Valley, California.

stow species is near the Tejon Hills form in many respects, but seems specifically distinct.

A lower cheek-tooth, no. 21484 (fig. 15), collected at Comanche

Creek in the Tejon Hills by R. C. Stoner has a short metaconid-metastylid column with the valleys anterior and posterior to this column narrower than in Barstow Miocene species which have been considered as very advanced *Merychippus*. In the first discussion of the Tejon Hills fauna[10] the writer assumed that the species represented by this tooth might be more progressive than the most advanced Barstow form, and specifically distinct from it. This tooth may represent a *Protohippus* differing from the Barstow Miocene forms to much the same degree as the upper cheek-tooth in the type of *Protohippus tehonensis* differs from them. It is possible that the specimen represents *P. tehonensis*. The proof of this will require more and better material than that now available.

PROSTHENNOPS, sp.

A number of fragments (no. 22459) from the Chanac formation represent a large peccary in which the cusps of the cheek-teeth are low or blunt-conical as in *Prosthennops*. This species approaches certain of the imperfectly known peccary forms from Pliocene faunas of the Pacific Coast and Great Basin regions. The material available from the Tejon Hills is too fragmentary, and the characters of the western Pliocene species are as yet too imperfectly known, to permit a satisfactory comparison.

CAMELID, indet.

A fragment of the distal end of a large metapodial (no. 22377) from locality 2751 represents a camelid possibly of the *Pliauchenia* type. Other very fragmentary material also indicates the presence of large camels, but the material available is not sufficient to furnish the basis for even a generic determination.

MERYCODUS, near NECATUS Leidy

Fragmentary material obtained in the Tejon Hills region by R. W. Pack has already made possible definite determination of the presence of *Merycodus* in this region. Additional specimens secured by the 1915 party include a fragment of a lower jaw, a lower tooth, a number of fragmentary horn-cores, a scapula, and a second phalanx. One horn-core specimen (no. 22332, fig. 17) resembles the type of *Merycodus* found in the Ricardo and Barstow faunas of the Mohave Desert, and referred to *M. necatus*. Other portions of horn-cores, in which the cross-section is nearly circular, suggests *M. furcatus*. The second phalanx agrees approximately in size of

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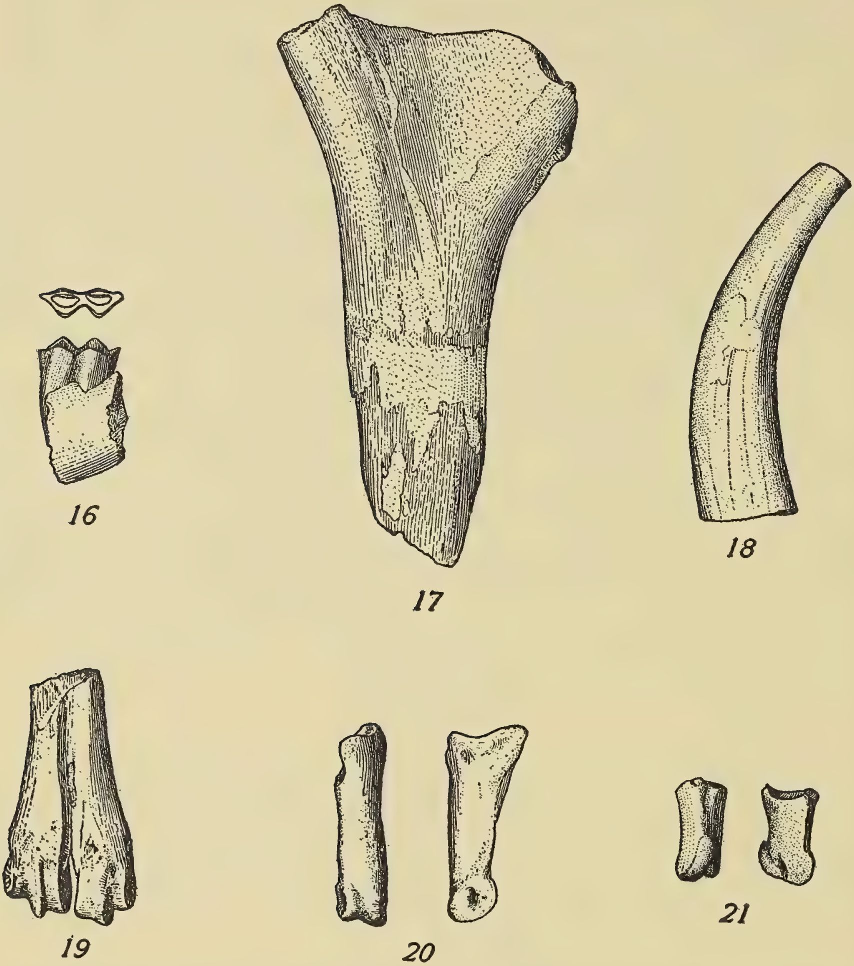
[10] Merriam, J. C., Univ. Calif. Publ., Bull. Dept. Geol., vol. 8, p. 287, 1915.



Figs. 16 to 21. *Merycodus* near *necatus* Leidy. All figures natural size. Chanac formation, southern end of San Joaquin Valley, California. Specimens represented in figs. 19 and 20 collected by R. W. Pack of U. S. Geol. Survey.

Fig. 16. M$\bar{2}$ or M$\bar{1}$, occlusal and outer views, no. 22366; fig. 17, flattened superior portion of beam, no. 22332; fig. 18, terminal portion of horn, no. 22367; fig. 19, distal end of metatarsus, anterior side; fig. 20, proximal phalanx, lateral and superior views; fig. 21, second phalanx, lateral and superior views, no. 22460.

corresponding parts with the first phalanx described in the earlier paper. The single lower tooth (no. 22366, fig. 16) is similar to $M\bar{2}$ or $M\bar{1}$ of a small species of *Merycodus* from the Ricardo. On the basis of the *Merycodus* material it is difficult to make a definite estimate of the age of the Chanac fauna, but the Tejon Hills form might well represent a stage near that of the Ricardo Pliocene.

Transmitted December 12, 1916

ORIGIN AND HISTORY OF THE BEAR FAMILY IN THE WESTERN HEMISPHERE, WITH PARTICULAR REFERENCE TO THE RELATION OF THIS QUESTION TO PROBLEMS OF GEOGRAPHICAL HISTORY

Although bears of many varieties are widely distributed in America and have been present in large numbers for a very long period measured in terms of years, the history of this group shows that as we go back in the geological record no evidence of representatives of the bear type are present in formations of the third geological period preceding the present in America, while they are known in considerable numbers in the rocks of this age found in the Old World. There is, therefore, good reason to believe that the bear group is derived from the other side of the earth and that the ancestors of the present American bears migrated to this continent at a time geologically not far removed from the present.

The bears of the world may be divided into two large groups, one sometimes known as the true bears, including the brown and grizzly types now widely distributed over the whole northern hemisphere. The second group is represented by the spectacle bear and is limited to the Andean region of South America.

In the geological period known as the Pleistocene, immediately preceding the present, true bears like the present black bear type were associated in North America with a group of large bears known as Arctotheres, closely related to the present spectacle bear of South America. In the same period South America was inhabited by numerous Arctotheres but contained no representatives of the true bears.

In the rocks of the Pliocene, or second geological period preceding the present, until recently no representatives of the bear group have been known in either North or South America. In the Pliocene deposits of Europe and Asia there are, however, remains of creatures closely related to the true bears and with these a second group originally known as the hyena bears, or the Hyaenarctos

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type, closely related in many characters to the Arctotheres, and through them related to the modern South American spectacle bears.

Assuming that the American bears are descendants of the Old World types, it is difficult to escape the conclusion that wide land connections existed between North America and Asia, and between North and South America, at such times as to permit the migration suggested by the present distribution. As the Arctotheres are represented in the Pleistocene of South America without accompanying true bears, it is logical to assume that the Arctothere group was the first to migrate to America and that it passed through North America reaching the South American region before the true bears had spread over North America. Investigations within the last few years have shown that in the Pleistocene deposits of North America both Arctotheres and true bears are present together down to the earliest strata in which remains of bears have been discovered. There has, therefore, been reason to assume that remains of Arctothere-like bears would be found in the Pliocene of America without associated remains of the true bear type. The point of the present paper is to call attention to the fact that recent carefully conducted investigations in the Pliocene deposits in several parts of North America have brought to light remains of bear-like forms which are intermediate between the typical hyena bears of the Old World Pliocene and the Arctotheres of the American Pleistocene. Such a form is represented by a specimen found in the Pliocene of Oregon. This animal corresponds very closely to the most specialized of the hyena bears of India and also approaches the Arctotheres in its structure.

The evidence now available indicates that creatures of the hyena bear type came by way of broad land connections from Asia to North America in Pliocene time; that these creatures represent the type of hyena bear most nearly approaching the Arctotheres and were widely distributed in North America. There is reason to believe that from this group the Arctotheres may have developed within the American region, and that the Arctotheres by way of a wide land bridge came to people South America.

The present spectacle bears of South America seem then to represent the last remnant of a group which originated in the Old World, was once widely distributed over the world, and included the largest of all known bears.

OCCURRENCE OF PLEISTOCENE VERTEBRATES IN AN ASPHALT DEPOSIT NEAR McKITTRICK, CALIFORNIA

Pleistocene mammalian remains from asphalt deposits located along the southwestern border of the Great Valley of California have been known since 1865, when Joseph Leidy reported the occurrence of two horse teeth from near Buena Vista Lake and referred the specimens to *Equus occidentalis.* Further remains of this species from the region of Buena Vista Lake were described and figured by Leidy[1] in 1873. Thirty years later J. C. Merriam[2] described a fragmentary lower jaw of the dire wolf, *Ænocyon dirus*, that apparently came from an asphalt bed in Tulare County, California.

The construction of the Taft-McKittrick highway in the petroleum producing belt southwest of Bakersfield has brought to light a fossiliferous bed of asphalt on the southern outskirts of the town of McKittrick. The deposit is apparently located in a narrow zone of asphaltic material shown on the geologic maps[3] of the McKittrick oil region as traversing the foothill region immediately southwest of McKittrick. As mapped by Arnold and Johnson this brea belt is associated areally with Pliocene and Miocene marine beds and is found also in contact with the alluvium of McKittrick Valley.

The occurrence of bones in asphalt near McKittrick was known for many years to the Department of Palæontology of the University of California. Recently John B. Stevens explored the deposit

By John C. Merriam and Chester Stock. *Science*, n. s., vol. 54, no. 1406, pp. 566–567, December 9, 1921.

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[1] Leidy, J., *Proc. Acad. Nat. Sci. Phila.*, 1865, p. 94; Rept. U. S. Geol. Surv. Terr., pp. 242–244, pl. 33, fig. 1, 1873.

[2] Merriam, J. C., Univ. Calif. Publ. Bull. Dept. Geol., Vol. 3, pp. 288–289, pl. 30, fig. 2, 1903.

[3] Arnold, R., and Johnson, H. R., "Preliminary report on the McKittrick-Sunset Oil Region, Kern and San Luis Obispo Counties, California," pl. 1, U. S. Geol. Surv. Bull. 406, 1910; Pack, R. W., "The Sunset-Midway Oil Field, California, Part I., Geology and Oil Resources," pl. 2, U. S. Geol. Surv. Prof. Paper 116, 1920.

and secured a number of specimens that were kindly presented to the University. During the past summer a field party from the Museum of Palæontology with cooperation and support of the Carnegie Institution of Washington, commenced excavations and made additional collections. Grateful acknowledgment should be made to the Midway Royal Oil Company for permission to excavate and for valuable assistance rendered during the progress of the work.

In the brea deposit near McKittrick a surface stratum of hardened asphaltic material reaches in places a thickness of several feet. This layer contains numerous remains of birds and mammals, apparently representing the Recent fauna, and overlies the deposit in which Pleistocene vertebrates are found. In excavating the older bed dense accumulations of mammalian remains were encountered. This deposit is in general comparable to those occurring at Rancho La Brea. The exhumed material was, however, not so well preserved as that from the asphalt bed near Los Angeles. This seems due, in a measure, to a prevailing earthy matrix showing somewhat less impregnation by petroleum than in the Rancho La Brea beds.

A small collection of bird remains from the McKittrick deposit was submitted to Dr. L. H. Miller for examination. A preliminary statement has been kindly given by Dr. Miller as follows:

> 1. Of the ten species thus far determined, six are aquatic or semi-aquatic in habit. With more careful examination to determine exact identity of ducks and waders, this proportion will be increased. Quite the reverse is true of the Rancho La Brea beds.
>
> 2. The golden eagle (*Aquila chrysaëtos*) is the most abundant species of land bird. One hawk (*Circus*), one caracara (*Polyborus*), and two falcons (*Falco sparverius* and *F.* near *fuscocerulescens*) are the only other raptors. No owls or vultures appear in the collection.
>
> 3. *Parapavo* is not represented. A single quail bone represents the great group of Gallinæ.
>
> 4. Shore birds (Limicolæ), so rare in the Rancho La Brea beds, are very abundant here. More specimens of this group are present in the collection of 100 specimens from McKittrick than in all the 50,000 examined from Rancho La Brea.
>
> 5. So far as examined there appear no extinct or extra-limital species not found at Rancho La Brea. On the other hand *Teratornis*, *Parapavo*, the great list of condors, vultures, eagles, old world vultures, and owls are thus far lacking.
>
> 6. The caracara, the indeterminate falcon, and the two storks, *Ciconia* and

Jabiru, give the same suggestion of semitropic climate as in the case of Rancho La Brea.

Following is a provisonal list of the Pleistocene mammalian fauna known from the McKittrick locality:

Ænocyon dirus (Leidy)
Canis, near *ochropus* Esch.
Felis atrox Leidy
Felis, near *daggetti* Merriam
Arctotherium, near *simum* Cope
Mylodon, sp.
Equus occidentalis Leidy
Antilocapra?, sp.
Bison, sp.
Camel, slender limbed form
Mastodon, sp.

Several of the mammalian species listed above are known from Rancho La Brea. The dire wolf (*Ænocyon dirus*), the great lion (*Felis atrox*) and the horse (*Equus occidentalis*) also occur in the asphalt beds near Los Angeles. Machaerodont cats have not been recognized at the McKittrick locality. The bear (*Arctotherium*) and the ground sloth (*Mylodon*) occur in both deposits, although the forms represented at McKittrick may be specifically separable from the types found at Rancho La Brea. A camel with slender limbs is certainly distinct from the large *Camelops hesternus* found at Rancho La Brea.

Further collecting at the McKittrick locality will bring out the relationship between this assemblage and the Rancho La Brea fauna. The contrasting features that are recognized at present may result from a geographic separation of the two asphalt deposits. It is probable that the environmental conditions prevailing in the southern portion of the Great Valley of California during the Pleistocene were somewhat unlike those existing in the vicinity of Rancho La Brea. On the other hand, it may be that the faunal differences are to be interpreted as indicating separate stages of the Pleistocene.

FAUNA OF THE PLEISTOCENE ASPHALT DEPOSITS OF McKITTRICK, CALIFORNIA

Fauna of the Pleistocene asphalt deposits of McKittrick, California: Dr. John C. Merriam, president of the Carnegie Institution of Washington, and Chester Stock, University of California. The discovery of an enormous accumulation of perfectly preserved remains of extinct animals found in asphalt beds in the environs of Los Angeles, California, some years ago furnished some of the most interesting data on the history of life thus far secured in America. A similar deposit representing an assemblage of animals of a somewhat different type has recently been opened for extensive investigation on the western border of the Great Valley of California. Remains of a wide variety of higher animals and birds were found at this new locality. The collection represents the geological period immediately preceding the present and offers the best opportunity thus far known to study the life of this late geological stage under the conditions obtaining in the Great Valley of California.

By John C. Merriam and Chester Stock. Abstract of paper presented at annual meeting of the National Academy of Sciences, Washington, April 24–26, 1922. *Science*, n. s., vol. 55, no. 1427, pp. 493–494, May 5, 1922.

A LLAMA FROM THE PLEISTOCENE OF McKITTRICK, CALIFORNIA

Introduction

In a provisional list of mammals from an asphalt deposit occurring near McKittrick,[1] Kern County, California, a slender-limbed camel was recognized as certainly distinct from the large *Camelops hesternus* known from Rancho La Brea. Since the preliminary account of the McKittrick asphalt deposit and fauna, further excavating at this locality has resulted in the collection of additional material of the small camel as well as of specimens of a type resembling closely the species *Camelops hesternus*. The slender-limbed camel is undoubtedly closely related to the living llama of South America, and, since this records, for the first time, the presence of the genus *Lama* in the Pleistocene of California, if not in that of North America,[2] a preliminary statement regarding the form seems desirable, in advance of a complete survey of the McKittrick mammalian assemblage now in progress. The authors appreciate the courtesy of officials of the Midway Royal Petroleum Company for extension of excavation privileges.

Lama stevensi, n. sp.

Type specimen.—A fragmentary mandible with lower dentition, No. 24260 Mus. Pale., Univ. of Calif., from Locality 4096, McKittrick, California. Named for Mr. J. B. Stevens, who brought the McKittrick deposit to the attention of the University of California.

Specific characters.—Type approaching in size the existing llama. Lower molars with enamel of internal faces not as distinctly folded as in existing llama. $M\bar{1}$ with median external style. $M\bar{2}$ and $M\bar{3}$

By John C. Merriam and Chester Stock. *Carnegie Institution of Washington Publication No. 347*, paper II, pp. 37–42, October 8, 1925.

[1] J. C. Merriam and C. Stock, Occurrence of Pleistocene vertebrates in an asphalt deposit near McKittrick, California. Science, n. s., vol. 54, pp. 566–567, 1921.

[2] J. W. Gidley records a llama from deposits of late Tertiary or Pleistocene age in San Pedro Valley, Arizona. (See J. W. Gidley, Preliminary report on fossil vertebrates of the San Pedro Valley, Arizona, with descriptions of new species of Rodentia and Lagomorpha, U. S. Geol. Surv., Prof. Paper 131, pp. 119–131, plates 34, 35, 1922.)

with antero-external style not as well developed as in *Lama.* Posterior or third lobe in $M\overline{3}$ not separated from second lobe as distinctly as in the corresponding tooth of the Recent *Lama.*

The material on which the present description is based consists of fragments of several mandibles and parts of the upper and lower dentition. While the collection unfortunately does not exhibit the important structures of the cranium, the remains of the lower jaw and of the dentition yield on study important data of use in the determination of the form.

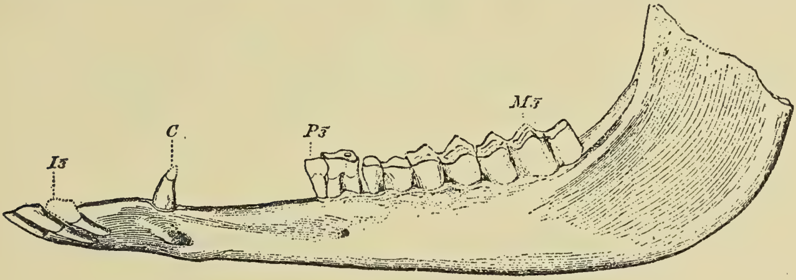

Fig. 1

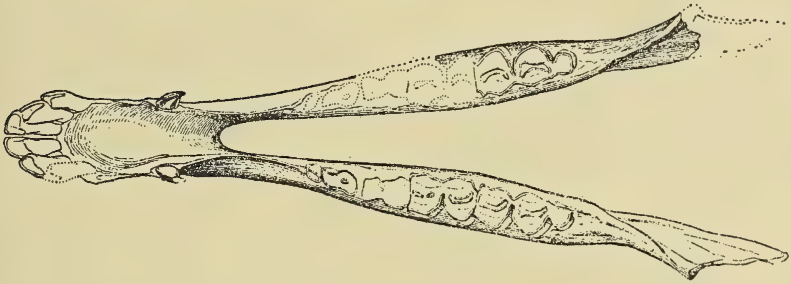

Fig. 2

Figs. 1 and 2. *Lama stevensi,* n. sp. Mandible No. 24260, Mus. Pale., Univ. of Calif. × 0.33. Fig. 1, lateral view; fig. 2, superior view. McKittrick Pleistocene.

The species from the McKittrick Pleistocene approaches in size the existing South American llama and may be found to average larger than this form. *Lama stevensi* is considerably smaller and less robust than *Camelops hesternus* (Leidy). In the mandible of the type specimen, No. 24260, figures 1 and 2, the vertical portion of the ramus is largely lacking. In the horizontal ramus the inferior border is practically straight in its extent from a point below $M\overline{3}$ to the symphysis. The symphyseal region is relatively longer and more slender than in the Recent *Lama*. The anterior mental foramen is large and is situated behind the inferior canine, while the posterior foramen is situated below the middle of $P\overline{4}$.

Judging from the material available, the Pleistocene species was characterized by a dental formula similar to that in the Recent llama. In the type specimen, $P\overline{3}$ is present, while in No. 24258 from McKittrick the tooth is absent. The corresponding tooth has not been noted in specimens of *Camelops hesternus* from Rancho La Brea.

An upper series of teeth, $P\underline{3}$ to $M\underline{3}$ inclusive, No. 24259, of *L. stevensi* is shown in figure 3. $P\underline{3}$ possesses a rather simple crown which closely resembles that in the corresponding tooth of *Lama*. A rudimentary fold of enamel extends inward from each end of the outer crest, but these folds do not meet in median line. The folds are better developed than in $P\underline{3}$ of *Camelops hesternus*. The middle internal root of this tooth may be united with both external, anterior and posterior, roots. In $P\underline{4}$ of No. 24259 the external enamel surface is folded not quite so strongly as in the existing llama. The superior molars exhibit less folding of the external enamel surface and the parastyle and mesostyle are less prominent in these teeth than in the living species.

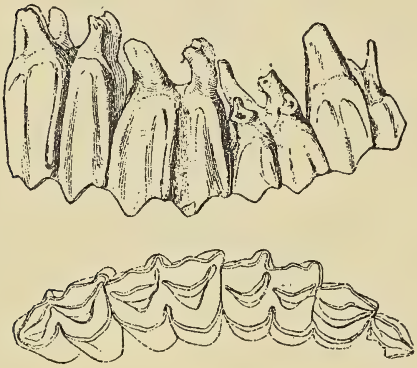

Fig. 3

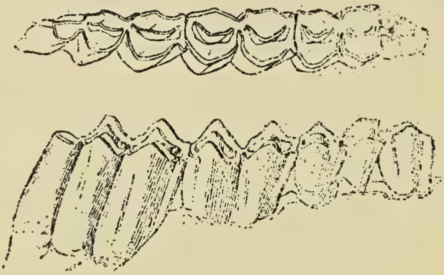

Fig. 4

Fig. 3. *Lama stevensi*, n. sp. Superior dentition, No. 24259, Mus. Pale., Univ. of Calif., lateral and occlusal views, × 0.50. McKittrick Pleistocene.

Fig. 4. *Lama stevensi*, n. sp. Inferior dentition, No. 24258, Mus. Pale., Univ. of Calif., occlusal and lateral views, × 0.50. McKittrick Pleistocene.

The lower incisors are relatively small. The lower canine approximates in size the tooth in the living llama, but the crown of the tooth appears to be less curved. $P\overline{3}$, present in No. 24260, is supported on a single root, and has a simple crown consisting of a single cusp compressed transversely. $P\overline{4}$ resembles that in *Lama*, but the anterior portion of the internal surface is apparently not so deeply infolded as in the latter form. In the slightly worn tooth, present in No. 24258, figure 4, a deep infolding of the enamel occurs on the posterior side, while in the specimen showing greater wear, No. 24260, this is replaced by a very small enamel lake.

The inner surface of the lower molars is noticeably less folded than in the existing llama. Each of the molar teeth in No. 24258 possesses a buttress or style at the outer forward end of the antero-external crescent, but this structure is not as prominent as in the living *Lama*. The style is not clearly seen in the molars of No. 24260, figure 1, because of the worn condition of these teeth. Merriam[3] states that this style is absent in $M\overline{2}$ and $M\overline{3}$ of *Camelops hesternus*.

$M\overline{1}$ in the type specimen is well worn. It is not so much worn in No. 24258. In this specimen $M\overline{1}$ exhibits a distinct style at the outer forward end of the postero-external crescent, just behind the median longitudinal groove. This style is absent in $M\overline{1}$ of the one specimen of the Recent llama available for comparison. The style is also absent in $M\overline{1}$ of *Camelops hesternus*. In $M\overline{3}$ the third or posterior lobe has a relative size comparable to that in living species. The inner surface of this lobe is not so distinctly set off from that of the second lobe as in the Recent *Lama*.

MEASUREMENTS (IN MILLIMETERS) OF MANDIBLE, No. 24260

Length of symphysis (approximate)	63
Least width behind inferior canine	27.8
Greatest height below anterior border of $P\overline{4}$	27
Greatest height below posterior border of $M\overline{3}$	51
Distance from posterior side of lower canine to anterior side of $P\overline{4}$ (approximate)	57

MEASUREMENTS (IN MILLIMETERS) OF SUPERIOR DENTITION, No. 24259

$P\underline{3}$, greatest antero-posterior diameter (taken at base of crown)	13
$P\underline{3}$, greatest transverse diameter (taken at base of crown)	8.8
$P\underline{4}$, greatest antero-posterior diameter	16.6
$P\underline{4}$, greatest transverse diameter	13.2

[3] J. C. Merriam, The skull and dentition of a camel from the Pleistocene of Rancho La Brea, Univ. Calif. Publ., Bull. Dept. Geol., vol. 7, No. 14, p. 315, 1913.

$M\underline{1}$, greatest antero-posterior diameter	25.8
$M\underline{1}$, greatest transverse diameter	21.5
$M\underline{2}$, greatest antero-posterior diameter	32.3
$M\underline{2}$, greatest transverse diameter	19.6
$M\underline{3}$, greatest antero-posterior diameter	28.2
$M\underline{3}$, greatest transverse diameter	17.1
Length from anterior side of $P\underline{3}$ to posterior side of $M\underline{3}$	104.3

MEASUREMENTS (IN MILLIMETERS) OF INFERIOR DENTITION

	No. 24260	No. 24258
$I\bar{1}$, transverse diameter	9.5	
$I\bar{2}$, transverse diameter	8.7	
$I\bar{3}$, transverse diameter	8.5	
Lower canine, antero-posterior diameter	8.7	
$P\bar{3}$, greatest antero-posterior diameter	9	
$P\bar{3}$, greatest transverse diameter	4.3	
$P\bar{4}$, greatest antero-posterior diameter	14.7	13.9
$P\bar{4}$, greatest transverse diameter	9.2	8.5
$M\bar{1}$, greatest antero-posterior diameter	18.8	21.3
$M\bar{1}$, greatest transverse diameter	13.1	14.6
$M\bar{2}$, greatest antero-posterior diameter	26.2	27.8
$M\bar{2}$, greatest transverse diameter	17	15
$M\bar{3}$, greatest antero-posterior diameter	36.6	34.7
$M\bar{3}$, greatest transverse diameter	16.1	14.8
Length from anterior side of $P\bar{3}$ to posterior side of $M\bar{3}$	101.7	
Length from anterior side of $P\bar{4}$ to posterior side of $M\bar{3}$	95.3	98
Length from anterior side of lower canine to posterior side of $M\bar{3}$	*a* 161	
Length from anterior side of $I\bar{3}$ to posterior side of $M\bar{3}$	*a* 222	

a Approximate.

RELATIONSHIPS AND STRUCTURE OF THE SHORT-FACED BEAR, ARCTOTHERIUM, FROM THE PLEISTOCENE OF CALIFORNIA

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INTRODUCTION

THE peculiar short-faced Californian bear, known as *Arctotherium simum*, was described by Cope in 1879 from a single specimen, consisting of a skull minus the lower jaw, found by J. A. Richardson in 1878 in Potter Creek Cave on the McCloud River in northern California. Since the description of *A. simum*, a nearly perfect skull with lower jaw and a large quantity of additional material, representing nearly all parts of the skeleton and dentition of this species, has been obtained from the deposits of Potter Creek Cave as a result of further work carried on for the University of California by E. L. Furlong and by W. J. Sinclair in 1902 and 1903.

Splendid material of *Arctotherium* has also been secured in the Pleistocene asphalt beds at Rancho La Brea by the Los Angeles Museum of History, Science, and Art. In 1911, J. C. Merriam

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By John C. Merriam and Chester Stock. *Carnegie Institution of Washington Publication No. 347*, paper I, pp. 1–35, pls. 1–10, October 8, 1925.

directed attention to the presence of arctotheres in the Pleistocene fauna from Rancho La Brea, describing a few remains collected in these beds by the University of California. While no complete skeleton has been exhumed, approximately eleven are known from Rancho La Brea. Recently a few belonging to arctotheres have been obtained in an asphalt deposit near McKittrick, California.

In the present paper an endeavor is made to review all available material of *Arctotherium* now in the Museum of Palaeontology, University of California, and in the Los Angeles Museum of History, Science, and Art. For permission to study the Rancho La Brea collection in the Los Angeles Museum and for the opportunity thus afforded to render a fuller statement regarding *Arctotherium* than could be given from an investigation of a single collection, the authors wish to express their sincere appreciation to Dr. Wm. Alanson Bryan, Director of the Museum. Thanks are extended to Dr. Joseph Grinnell, Director of the Museum of Vertebrate Zoology, University of California, and to the United States National Museum for the loan of specimens of Recent bears. The illustrations have been prepared by John L. Ridgway.

Systematic Position of Arctotherium and Its Allies with Relation to the Typical Ursidae

The bears of the western hemisphere, including both Recent and Pleistocene forms, are divisible into well-defined groups. One is represented by the typical *Ursus*, including several groups of species,[1] by *Evarctos* and by *Thalarctos*. The other group contains the living *Tremarctos* of South America and the allied fossil species of both South and North America included in the genus *Arctotherium*. The second of these divisions is separated from the typical bears by the following characters:

(1) Skull with facial and frontal regions relatively short and broad.
(2) General presence of more than one infraorbital and of more than two incisive foramina.
(3) Great anterior extension and depth of masseteric fossa and its division by a high, sharp ridge into two distinct excavations.
(4) Dental series generally closed.
(5) P$\underline{4}$ with metacone forming a shearing blade.

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[1] For a recent review of some of the living bears of North America see C. Hart Merriam, North American Fauna, No. 41, U. S. Depart. Agriculture, Bur. Biol. Surv., 1918.

(6) $M\underline{1}$ and $M\underline{2}$ relatively short and broad.
(7) $M\overline{1}$ with trigonid trenchant rather than crushing, and without accessory tubercles.
(8) Atlas with posterior opening of vertebrarterial canal on upper side of transverse process in advance of posterior edge.
(9) Humerus with entepicondylar foramen.

Both of these groups have been represented in North America at least as far back as Middle Pleistocene time, and occur in deposits of both the Atlantic and Pacific coasts. As far back as they have been traced in America the distinctive characters continue to separate them, and are in fact more strongly expressed in some of the oldest forms known than in the existing species. The differences between the groups are greater than those ordinarily separating genera, and if we bring the classification of the bears to a level on which it will express the true relationships within the family they must be known as subfamilies. To represent their positions more distinctly, it is proposed that the name Arctinae[2] be applied to the first group and Tremarctinae to the second.

Within the Tremarctinae are two small groups represented by *Tremarctos* and *Arctotherium*. The true *Tremarctos* is known only in the Recent fauna, while *Arctotherium* is extinct. The typical *Arctotherium* is distinguished from the typical *Tremarctos* by its larger size, shorter head, simpler teeth, and ordinarily by a larger number of infraorbital foramina. If we had only the typical specimens of *Arctotherium* and *Tremarctos*, there would be no difficulty in distinguishing the two genera, but there exists in *Arctotherium* (*Ursus*) *haplodon* Cope of the Port Kennedy Fissure, Pennsylvania, a form which is in many respects intermediate. This species was referred by Cope to *Ursus*, as he was uncertain concerning the character of the lower jaw in *Arctotherium*. Arctothere material from Potter Creek Cave and from Rancho La Brea in California shows the lower jaw to be essentially as in the South American *Arctotherium* or in *Tremarctos*. In most points the characters of the skull and dentition in the type from Pennsylvania are those of *Arctotherium*, but M$\underline{1}$ is narrower than in typical *Arctotherium* and M$\underline{2}$ has a larger heel than is seen elsewhere in that genus. The skull is imperfectly preserved in the specimen studied by Cope and is not well prepared, so that it has not been possible to make a satisfactory examination of the infraorbital foramina, but there appears to be but one opening. In all of these characters this specimen approaches the living *Tremarctos* of South America more closely than does any other form of *Arctotherium*. This species makes the separation of the two types more difficult. Nevertheless, they are to be considered as representing fairly distinct generic or subgeneric groups.

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[2] The name Ursinae has been used by Lydekker (1884, p. 239) to include *Ursus*, *Arctotherium*, and *Hyaenarctos*, contrasted with the dogs (Caninae) in his Ursidae; by Trouessart for the true bears, *Tremarctos*, *Melursus*, and *Hyaenarctos*, separated from the Ailurinae including *Ailuropus* and *Ailurus*; by Burmeister (1866, p. 144) to include the South American *Tremarctos*, *Arctotherium*, *Procyon cancrivorus*, and *Nasua socialis*; and by Winge (1895, p. 46) to include *Amphicyon*, *Simocyon*, *Hemicyon*, *Hyaenarctos*, *Aeluropus*, *Arctotherium*, *Melursus*.

TABLE 1

Themarctos	Arctotherium	Hyaenarctos
1. Skull short and broad.	Skull short and broad.	Skull short and broad.
2. One infraorbital foramen.	2 or more infraorbital foramina.	3 infraorbital foramina.
3. Median incisive foramen large.	Median incisive foramen large.	
4. Double masseteric fossa.	Double masseteric fossa.	Long, partly divided masseteric fossa.[3]
5. P$\underline{4}$ with metacone tending to form shearing blade; protocone opposite notch between paracone and metacone.	P$\underline{4}$ with metacone tending to form shearing blade; protocone opposite notch between paracone and metacone.	P$\underline{4}$ with metacone as shearing blade; protocone anterior in position.
6. M$\underline{1}$, longer than wide; 3 inner tubercles; metastyle present.	M$\underline{1}$, square or slightly longer than wide; 3 inner tubercles; metastyle may be present.	M$\underline{1}$, square; inner tubercles; incipient metastyle present.
7. M$\underline{2}$, heel not long or narrow, but relatively broad.	M$\underline{2}$, heel relatively short and narrow.	M$\underline{2}$, without heel.[4]
8. M$\overline{1}$, protoconid and paraconid forming shearing blades.	M$\overline{1}$, protoconid and paraconid forming shearing blades.	M$\overline{1}$, protoconid and paraconid forming shearing blades.
9. Humerus with entepicondylar foramen.	Humerus with entepicondylar foramen.	Humerus not known.[5]

In the comparative table above a number of characters are listed in which *Tremarctos* and *Arctotherium* show distinctly closer affinity to *Hyaenarctos* and its allies of the Pliocene than is seen in the Pleistocene and Recent bears of the genus *Ursus*.

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[3] Double masseteric fossa apparently present in *Agriotherium* (*Hyaenarctos*) *schneideri* Sellards.

[4] M$\underline{2}$ with short and broad heel in *Indarctos salmontanus* Pilgrim and in *Indarctos? oregonensis* Merriam, Stock, and Moody.

[5] Humerus with entepicondylar foramen in *Indarctos? oregonensis* Merriam, Stock, and Moody.

Origin of the Tremarctinae

Within the past few years notable additions have been made to our knowledge of the bears of the late Tertiary. Hyaenarctid bears of the genera *Hyaenarctos* and *Indarctos* were regarded until recently as characteristic of the Old World, but close relatives of these forms are now known to occur in Pliocene deposits in North America.

Since the tentative determination of *Hyaenarctos* by Freudenberg (1910, pp. 205–209, pl. 21, fig. 2; pl. 22, fig. 2) from the brown coal of Tehuichila near the boundary between the States of Hidalgo and Vera Cruz, Mexico, hyaenarctid remains have been described by Sellards (1916) from Florida, by Merriam, Stock, and Moody (1916) from eastern Oregon, and by Childs Frick (1921) from southern California.

The occurrence in the North American Pliocene of forms of the *Hyaenarctos* type, with characters tending toward those of *Arctotherium* and *Tremarctos*, gives support to the assumption that the American Tremarctinae of the Pleistocene and Recent periods represent a line passing through or very close to the *Hyaenarctos* group. It is now possible to consider the origin of the Pleistocene members of the Tremarctinae in America rather than in Eurasia.

We may conceive of *Arctotherium*, or its immediate predecessor, as originating in North America in the Pliocene and entering South America after the land connection between the two continents was established.

Two forms from South America described by Ameghino (1889) as *Pararctotherium* and *Proarctotherium* have been assumed to be ancestral types of the South American arctotheres. *Pararctotherium* is known from the Pampean formation, which corresponds to a considerable portion of the Pleistocene of North America. *Pararctotherium* is clearly a member of the *Arctotherium* group in which $M\bar{2}$ is considerably specialized. The anterior premolars of *Pararctotherium* are crowded, and the facial region was evidently shortened. There is no good reason for considering that this type is ancestral to

Arctotherium; in fact, it may be one of the more specialized members of the *Arctotherium* group.

Proarctotherium is known from a very fragmentary specimen consisting of $M\bar{2}$ and $M\bar{3}$ from Parana. The Parana deposits have been assumed to be Pliocene, and may contain a small number of North American Pliocene types. Ameghino's figure (Ameghino, 1889, p. 319, pl. 21, fig. 1) of the type specimen shows a $M\bar{2}$ not differing materially from that of *Arctotherium*. $M\bar{3}$ is large and elongate, approximating the form seen in typical Pleistocene *Arctotherium*, as in *A. simum*.

The type specimen of *Proarctotherium* evidently represents a typical member of the *Arctotherium* group. As the occurrence of a representative of the *Hyaenarctos* type seems now fairly established for the late Tertiary of Mexico, it is of course possible that a member of the group reached South America with the earliest of the emigrants from North America. While the characters of $M\bar{2}$ in the Parana form do not differ greatly from those of *Hyaenarctos*, $M\bar{3}$ is of a distinctly more advanced type. The nature of the specialization of $M\bar{3}$ is such as we commonly find associated with an anteroposteriorly elongated heel of the last upper molar and is not to be expected in a Pliocene bear. Apparently the geologic occurrence of the Parana specimen must remain in doubt until other material of this nature appears in the Parana.

Summary of Species of Arctotherium in the Pleistocene of North America

Five species of arctotheres have been described from the Pleistocene of North America: *Arctodus pristinus* Leidy; *Arctotherium simum* Cope; *Arctotherium haplodon* Cope; *Arctotherium yukonense* Lambe; *Arctotherium californicum* J. C. Merriam.

Arctodus pristinus was described from South Carolina by Leidy (1854). Leidy's later description of *Arctodus* (Leidy, 1860) is accompanied by figures of the type specimen, an unworn second lower molar. *Arctodus* therefore seems determinable, but the writers hesitate to assign this form to the generic group to which the later described arctotheres of North America have been referred until Leidy's original material can be examined. Should the characters of *Arctodus* be shown eventually to agree with those of

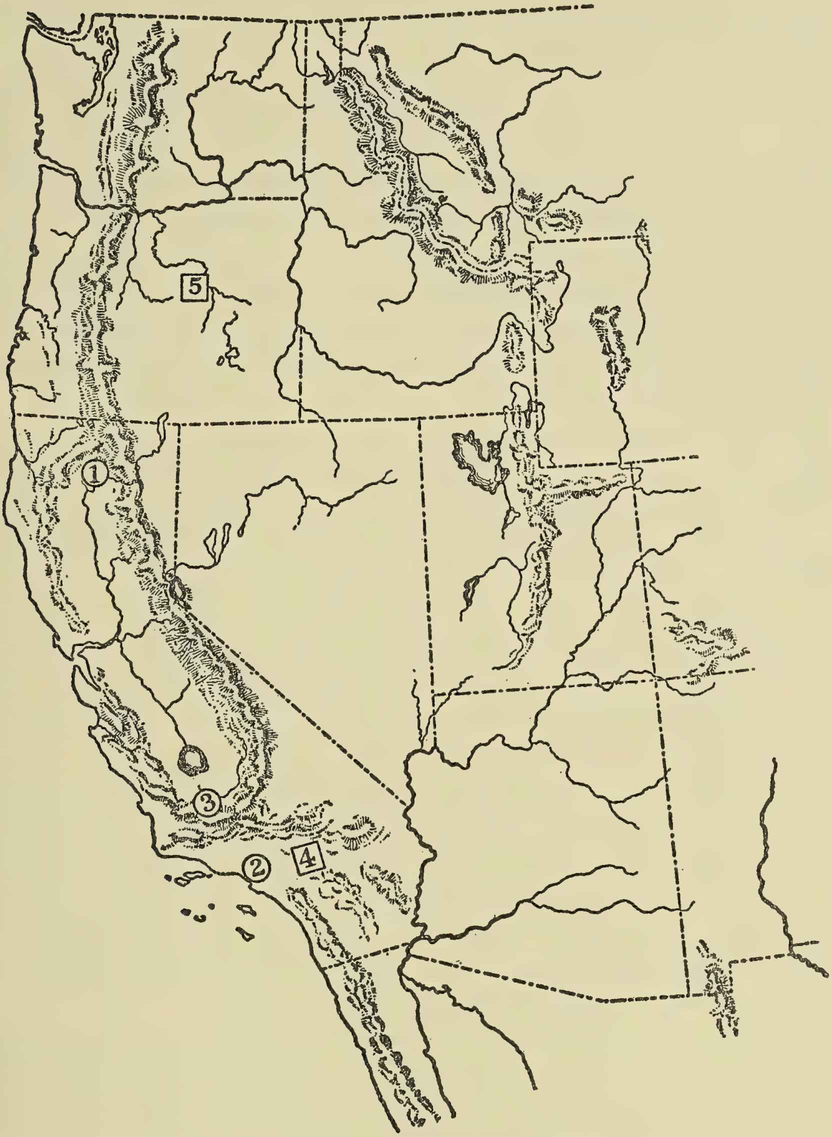

Fig. 1. Outline map showing known occurrences of Pleistocene and Pliocene bears in the United States west of the Wasatch Range. (1) *Arctotherium simum* Cope, Potter Creek Cave, Shasta County, California; (2) *Arctotherium californicum* Merriam, Rancho La Brea, California; (3) *Arctotherium*, near *simum* Cope, McKittrick, California; (4) *Hyaenarctos gregoryi* Frick, Pliocene Eden beds near Beaumont, California; (5) *Indarctos? oregonensis* Merriam, Stock and Moody, Pliocene Rattlesnake beds, Eastern Oregon.

Arctotherium, the former name has priority, for *Arctodus* antedates *Arctotherium* Bravard.

A. haplodon from the Port Kennedy Fissure, Pennsylvania, seems considerably nearer to the existing species of *Tremarctos* of South America than is *A. simum.* It seems to be also the nearest of all the *Arctotherium* species to *Tremarctos* forms, but in spite of a stronger resemblance to *Tremarctos* is still apparently a typical *Arctotherium.*

A. yukonense from Gold-Run Creek, Yukon, is based by Lambe (1911) on a skull that exceeds in size the specimen described by Cope as *A. simum.* In several characters *A. yukonense* exhibits similarity to *A. simum.*

A. simum was described by Cope (1879; 1891) from northern California, while *A. californicum* was determined by J. C. Merriam (1911) on a small collection consisting principally of metapodials secured at Rancho La Brea, California. The type from the asphalt beds was decidedly larger than representatives of *Arctotherium simum* from Potter Creek Cave and the two forms were regarded as specifically distinct. It appears evident, from present study, that the disparity in size between the arctotheres of northern and southern California may not be greater than that falling within the limits of sexual variation in some living bears.

Until the time relationship of the mammalian faunas from Potter Creek Cave and from Rancho La Brea can be definitely established, it seems desirable to recognize the arctothere from the latter deposit as a species or at least as a subspecies, distinct from *A. simum.* Considering the North American members of the genus, *Arctotherium simum*, *A. californicum*, and perhaps *A. yukonense*, represent a group of very closely related species.

OCCURRENCE IN CALIFORNIA OF ARCTOTHERES AND ASSOCIATED FAUNAS

Potter Creek Cave

The occurrence of vertebrate remains in the Pleistocene deposits of Potter Creek Cave, Shasta County, California, has been fully discussed by W. J. Sinclair (1904). The deposits which accumulated in this cave consisted in large part of reddish cave-earth interstratified with gravel or rubble layers and stalagmitic materials. The depth to which excavation could be carried varied considerably in different portions of the cave, the greatest depth reached being about 25 feet. The stratigraphy of the deposits was determined with little difficulty in most cases and over a large portion of the cave it was possible to determine the time of entombment of each specimen with reference to the time of burial of other remains nearby.

Remains of *Arctotherium* were found scattered through the greater part of the cave accumulation. The bones were in most instances disconnected and scattered about, but near the middle of the cave many of the bones of several individuals were found together. The skull described by Cope was obtained at this place, and presumably belongs to an individual represented by one of the skeletons now in the collection of the University of California.

It is interesting to note that the arctotheres, while associated with the genus *Ursus* in the Pleistocene mammalian assemblage living in the region of Potter Creek Cave, were represented by a greater number of individuals than were the latter.

The mammalian fauna of Potter Creek Cave contains the following forms:

Scapanus latimanus (Bachman).
Antrozous pallidus pacificus C. H. Merriam.
Arctotherium simum Cope.
Ursus n. sp.
Aenocyon dirus (Leidy).
Vulpes cascadensis C. H. Merriam.
Urocyon cinereoargenteus townsendi C. H. Merriam.
Bassariscus astutus raptor (Baird).
Mustela arizonensis (Mearns).
Spilogale n. sp.
Mephitis occidentalis Baird.
Taxidea n. sp. (?).
Felis, probably n. sp.
Felis n. sp.
Lynx fasciatus Rafinesque.
Lynx fasciatus n. subsp. (?).
Neotoma cinerea occidentalis Baird.
Microtus californicus (Peale).
Thomomys microdon Sinclair.
Thomomys leucodon C. H. Merriam.
Aplodontia californica fossilis Sinclair.
Marmota flaviventer (Audubon and Bachman).
Citellus beecheyi douglasi (Richardson).
Eutamias sp.
Callospermophilus chrysodeirus (C. H. Merriam).
Sciurus douglasi albolimbatus Allen.
Sciuropterus alpinus klamathensis C. H. Merriam.
Sylvilagus auduboni (Baird).
Nothrotherium shastense Sinclair.
Megalonyx wheatleyi (?) Cope.
Megalonyx jeffersonii (?) (Desmarest).
Megalonyx n. sp.
Megalonyx sp.
Camelid.
Bison sp.
Odocoileus sp. a.
Odocoileus sp. b.
Euceratherium collinum Sinclair and Furlong.
Oreamnos americanus (Ord).
Platygonus (?), sp.
Equus occidentalis Leidy.
Equus pacificus Leidy.
Mammut americanum (Kerr).
Elephas primigenius Blumenbach.

Rancho La Brea

Remains of arctotheres were first encountered at Rancho La Brea during the investigation conducted by the Department of Palaeontology, University of California. Later work by the Los Angeles Museum resulted in the collection of much additional material, representing probably not less than eleven individuals. A nearly complete skull and well-preserved limb elements were obtained in Pit 60 excavated by the Los Angeles Museum. Further notable collections were made by the Museum in Pits 77, 17, 9, and scattered materials have been obtained from other excavations. It is evident that *Arctotherium* was a contemporary of the typical Pleistocene mammalian assemblage from Rancho La Brea and was one of the largest of the carnivores occurring in this fauna. We note again an occurrence of this type in greater numbers than the bears of the genus *Ursus*. The mammals identified in the Rancho La Brea fauna are listed as follows:

- Carnivora:
  - Arctotherium californicum Merriam, J. C.
  - Ursus sp.
  - Aenocyon dirus (Leidy).
  - Aenocyon milleri (Merriam, J. C.)
  - Canis occidentalis furlongi Merriam, J. C.
  - Canis ochropus orcutti Merriam, J. C.
  - Canis andersoni Merriam, J. C.
  - Urocyon californicus Mearns.
  - Taxidea, possibly n. sp.
  - Mephitis occidentalis n. subsp.?
  - Spilogale sp.
  - Mustela sp.
  - Smilodon californicus Bovard.
  - Felis atrox bebbi Merriam, J. C.
  - Felis daggetti Merriam, J. C.
  - Lynx ruffus californicus Mearns.
- Edentata:
  - Mylodon harlani Owen.
  - Mylodon harlani tenuiceps Stock.
  - Megalonyx jeffersonii californicus Stock.
  - Nothrotherium shastense Sinclair.
- Artiodactyla:
  - Camelops hesternus (Leidy).
  - Capromeryx minor Taylor.
  - ?Antilocapra americana (Ord).
  - Odocoileus, sp.
  - Bison antiquus Leidy.
  - Platygonus, possibly n. sp. or n. subsp.
- Perissodactyla:
  - Equus occidentalis Leidy.
  - ?Tapirus sp.
- Proboscidea:
  - Mammut americanum (Kerr)?
  - Elephas imperator Leidy?
- Many rodents and lagomorphs.

McKittrick

Excavation in an asphalt deposit near McKittrick, California, by the Carnegie Institution of Washington in cooperation with the Museum of Palaeontology of the University of California has yielded a Pleistocene fauna somewhat different from that of Rancho La Brea. A preliminary survey of the mammalian assemblage by Merriam and Stock[6] shows the presence of the following forms:

Arctotherium, near simum Cope.
Aenocyon dirus (Leidy).
Canis, near ochropus Esch.
Felis atrox Leidy.
Felis, near daggetti Merriam, J. C.
Mylodon? sp.
Taxidea sp.
Equus occidentalis Leidy.
Antilocapra? sp.
Bison sp.
Camel, slender-limbed form (Lama).
Camelops sp.
Mammut, near americanum (Kerr).

To this list other forms will probably be added as the excavation progresses and the fauna is studied in greater detail. Remains of *Arctotherium* are still incomplete, consisting only of a few teeth. The specimens represent a type close to *Arctotherium simum*.

ODONTOLOGY AND OSTEOLOGY OF ARCTOTHERIUM

In the following description of *Arctotherium* from the Pleistocene of California the principal comparisons have been made on the one hand with known representatives of the Pliocene hyaenarctid group and on the other with existing members of the genera *Ursus* and *Tremarctos*. A skull and a skeleton of *Tremarctos ornatus* from South America (Nos. 171011 and 194309, U. S. Nat. Mus.) were available, and of the genus *Ursus* the skull and skeletal material of brown, black, and grizzly bears in the collections of the Museum of Vertebrate Zoology, University of California, were used.

Dentition

Dental formula: $\frac{3}{3}\Big|\frac{1}{1}\Big|\frac{4}{4}\Big|\frac{2}{3}$

Incisors $\underline{1}$ and $\underline{2}$ are of nearly equal size, while incisor $\underline{3}$ is distinctly larger. The canine is relatively heavier than in *Tremarctos*. The crowns have the dimensions and proportions near those of *Indarctos? oregonensis* from the Rattlesnake formation (Lower Pliocene) of eastern Oregon. The roots may be smaller, relative to the size of the crown in *Arctotherium*, but are not thinner in either transverse or anteroposterior diameter. The three anterior premolars are single-rooted and are situated close together as in *Tremarctos*.

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[6] Science, n. s., vol. 54, pp. 566–567, 1921.

P$\underline{1}$ is larger than P$\underline{2}$ or P$\underline{3}$. The crown of the tooth has a single cusp, which in the skull, No. 3001 U. C. C., from Potter Creek Cave, is excavated considerably on the inner side of the base. P$\underline{2}$ is missing in the specimens from California, but according to the alveolus it was smaller than P$\underline{1}$ (plate 5, fig. 2).

P$\underline{4}$ is three-rooted. In this tooth the metacone tends to form a shearing blade as in *Tremarctos* (plate 5, figs. 1 and 2). In *Ursus* the metacone tends to be conical. The position of the protocone is opposite the notch between paracone and metacone, as in *Tremarctos.* This cusp varies somewhat in size, but is not as large as the cusp in *Hyaenarctos* and in *Indarctos* (plate 5, fig. 3). In *Ursus* the protocone seems generally to be situated slightly farther posteriorly than in *Arctotherium.* The position of the protocone is distinctly farther back than in *Hyaenarctos* and in modern carnivores in which this cusp is normally located at the inner side of the anterior end of the tooth. The parastyle, which is so largely developed in *Indarctos? oregonensis* and in *Hyaenarctos*, is absent in *Arctotherium*, but may be suggested in some specimens. The parastyle is figured by Blainville[7] in his illustration of the dentition of *Tremarctos ornatus*, but is absent in specimen 171011 of the U. S. National Museum.

M$\underline{1}$ is three-rooted. The largest but shortest root supports the inner side. The two outer roots support principally the paracone and metacone. The root supporting the metacone is the larger of the two. The crown of this tooth has more the proportions of M$\underline{1}$ of *Hyaenarctos* than of either *Ursus* or *Tremarctos.* M$\underline{1}$ in the arctotheres of California approaches more nearly a perfect quadrate form than in other known species of *Arctotherium.* It is much nearer the square form in *A. simum* than in *A. bonaerense.* No cingulum is present along the inner side, as in *Ursus*, in which respect *Arctotherium* is more like *Tremarctos.* The antero-internal end of the tooth is angular, however, due to a variable development of a cingulum, making this part nearer rectangular and much more prominent than in *A. bonaerense* or in other species.

The paracone and metacone are the prominent cusps on the crown of M$\underline{1}$. In contrast to the tooth in *Hyaenarctos* a parastyle is present and a style posterior to the metacone (metastyle) is also developed. The metastyle and particularly the parastyle are more prominent features in *Arctotherium* than in *Ursus* or in *Tremarctos*. A cingulum may be faintly defined along the outer base of the metacone. In M$\underline{1}$ of *Hyaenarctos gregoryi* according to Frick (1921, p. 342, figs. 51*a* and 51*b*) a marked cingulum is lacking. Of the three distinct internal tubercles in M$\underline{1}$ of *A. simum*, the middle one is usually the largest or longest; it is relatively more prominent than in *Ursus*. In *Tremarctos* an inner ridge is present and does not show clear division into tubercles, as in *Arctotherium*. This seems to be true also for *Hyaenarctos gregoryi*. The ridge connecting the antero-internal cusp with the parastyle is not so pronounced as in *Ursus*. Between the principal inner and outer cusps are several minor tubercles, while in this region in M$\underline{1}$ of *Tremarctos* the enamel is crenulated. A character found in this tooth of *Arctotherium*, which is not seen in other bears, is the presence of a tubercle (hypostyle) near the middle of the posterior side.

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[7] H. M. D. Blainville, Ostéographie des mammifères, Atlas 2, pl. 12, 1864.

In M$\underline{2}$ there were evidently four original root elements. The roots beneath paracone and metacone tend to diverge widely, the element below the metacone being in some cases united with the posterior root supporting the heel. In *Arctotherium* the root supporting the protocone may or may not unite with the root below the heel. The corresponding tooth of *Indarctos? oregonensis* has two distinct external roots supporting paracone and metacone, but they do not diverge. The inner and posterior regions are supported by a large, broad root comparable to that occurring in most specimens of *Arctotherium* from California.

The crown of M$\underline{2}$ is a little narrower than in *A. bonaerense*. Like M$\underline{1}$ the anterior inner corner is nearly rectangular, owing to the prominence of the cingulum. The transverse width across the paracone is greater than that across the metacone, as in *Indarctos? oregonensis* (plate 5, fig. 4), while in *Ursus* and in *Tremarctos* this difference is not so noticeable. No cingulum is present along the inner side, in which character *Arctotherium* agrees with *Tremarctos* and differs from *Ursus*. The inner tubercles are faintly indicated.

M$\underline{2}$ differs from that of *Indarctos? oregonensis* in its smaller width and much longer talon. In *Arctotherium* the primitive quadritubercular portion of the tooth is longer anteroposteriorly and the heel is much longer. The arrangement of the tubercle is much the same in the two types, but the tubercles show stronger lateral compression in *Arctotherium*.

The crown of the lower canine in *A. simum* is sharply concave on the posterior side. The three anterior premolars of the lower dentition have simple cusps and are single-rooted teeth, as in *Tremarctos* (plate 5, figs. 5 and 6). In *Hyaenarctos punjabiensis*, as figured by Lydekker (R. Lydekker, 1884, pl. 31, fig. 1 and 1*a*) there are only two alveoli present in front of P$\bar{4}$. According to Sellards (1916, p. 99) a single alveolus, probably for P$\bar{2}$, is present in *Agriotherium* (*Hyaenarctos*) *schneideri* anterior to P$\bar{4}$ (plate 5, fig. 7).

P$\bar{4}$ has a larger crown than in the preceding teeth in *Arctotherium*, with a single cusp as in *Tremarctos* and in *Ursus*. The two roots have fused. In *Tremarctos* and in *Ursus* the roots are separated. In the Indian *Hyaenarctos* and in the Florida *Agriotherium* P$\bar{4}$ is a much larger tooth than in *Arctotherium*. In the Florida specimen (plate 5, fig. 7), as shown by Sellards, P$\bar{4}$ possesses an anteroposterior diameter which is approximately half that of M$\bar{1}$. The crown of the tooth is supported by two large roots.

M$\bar{1}$ in *Arctotherium* resembles this tooth in *Tremarctos* and differs from that in *Ursus* in possessing a shearing trigonid region. In M$\bar{1}$ of *Ursus* a series of tubercles extends forward from the metaconid to the paraconid, giving a crushing trigonid region. *Arctotherium* also resembles *Hyaenarctos* in having a shearing trigonid. In *Agriotherium* (*Hyaenarctos*) from Florida, along the inner side of the base of the paraconid, there is present a vestige of a cingulum which is absent in *Arctotherium* and in the Indian *Hyaenarctos punjabiensis*. M$\bar{1}$ in *Arctotherium* does not taper to the anterior end so noticeably as in the Recent or Pliocene members of the Tremarctinae.

The metaconid in M$\bar{1}$ is relatively smaller than in *Ursus*. In *Hyaenarctos* this cusp is quite prominent. In *Arctotherium* the outer side of M$\bar{1}$ is deeply indented between trigonid and talonid regions—more so than in *Hyaenarctos* and distinctly more so than in *Tremarctos*. The entoconid is relatively farther forward than in *Ursus*, *Arctotherium* resembling *Hyaenarctos* and *Tremarctos* in this respect.

M$\bar{2}$ of *Arctotherium* resembles the tooth in *Hyaenarctos*, and differs from that in *Ursus* in possessing a transverse diameter across the trigonid region which is greater than that across the talonid region. The trigonid region is basin-shaped and is bordered posteriorly by the large protoconid and metaconid. The talonid region is relatively short as in *Hyaenarctos* and *Tremarctos*, differing in this respect from that in *Ursus*. The crown of M2̄ shows a smaller number of tubercles than in *Ursus*, but a greater number than in *Hyaenarctos*.

M3̄ is supported by a single root. The crown is subtriangular, differing in shape from that in *Hyaenarctos*. It is bordered by a low rim of enamel within which the surface is marked by a number of small papillae. In lacking a decided tuberculation the occlusal surface in this tooth resembles that in *Tremarctos* and differs from that in *Ursus*.

That the molar teeth may vary in size independently of the size of the skull is indicated by specimens of the lower jaw from Rancho La Brea. In No. Z 29, M1̄ and M2̄ are larger than the corresponding teeth in No. Z 7, yet the ramus of the former, measured between these teeth, shows a height 15 mm. less than in the latter.

TABLE 2

MEASUREMENTS (IN MILLIMETERS) OF DENTITION OF ARCTOTHERIUM SIMUM FROM POTTER CREEK CAVE, NO. 3001, UNIVERSITY OF CALIFORNIA COLLECTION

	No. 3001.
Greatest transverse diameter of incisor series, measured at cingulum of I3̲	57.2
Length from anterior side of C̲ to posterior side of M2̲	136.8
Length from anterior side of P4̲ to posterior side of M2̲	76
I1̲, greatest transverse diameter	7.9
I2̲, greatest transverse diameter	9
I3̲, greatest transverse diameter	10.8
C̲, anteroposterior diameter at base of enamel	27.9
P1̲, greatest anteroposterior diameter	10.4
P3̲, greatest anteroposterior diameter	8.5
P3̲, greatest transverse diameter	5
P4̲, greatest anteroposterior diameter	20.5
P4̲, transverse diameter across protocone	15
M1̲, greatest anteroposterior diameter	24
M1̲, greatest transverse diameter	23
M2̲, greatest anteroposterior diameter	35
M2̲, greatest transverse diameter	22
Length from anterior side C̄ to posterior side of M3̄	155
Length from posterior side C̄ to anterior side of M1̄	46
Length from anterior side M1̄ to posterior side of M3̄	77
C̄, anteroposterior diameter at base of enamel	39
P4̄, anteroposterior diameter	12.5
P4̄, transverse diameter	7.8
M1̄, anteroposterior diameter	31.5
M1̄, transverse diameter across protoconid	15
M1̄, width of heel	16
M2̄, anteroposterior diameter	27
M2̄, transverse diameter across protoconid	19.5
M3̄, anteroposterior diameter	20
M3̄, transverse diameter across protoconid	16

TABLE 3

Measurements (in Millimeters) of Dentition of Arctotherium californicum. Los Angeles Museum Collections

	No. Z 1.	No. Z 2.	No. Z 4.	No. Z 5.
Greatest transverse diameter of incisor series, measured at cingulum of I$\underline{3}$	64.2	......	......	......
Length from anterior side of $\underline{C}$ to posterior side of M$\underline{2}$	144.4	......	145.6	......
Length from anterior side of P$\underline{4}$ to posterior side of M$\underline{2}$	80.8	81.3	......	......
I$\underline{1}$, greatest transverse diameter	8.9	......	......	......
I$\underline{2}$, greatest transverse diameter	9.2	......	......	......
I$\underline{3}$, greatest transverse diameter	10.7	......	......	......
$\underline{C}$, anteroposterior diameter at base of enamel	29.3	......	26.5	......
P$\underline{1}$, greatest anteroposterior diameter	......	......	......	......
P$\underline{2}$, anteroposterior diameter of alveolus	6.5	......	......	......
P$\underline{3}$, greatest anteroposterior diameter	7.9	......	......	......
P$\underline{3}$, greatest transverse diameter	5	......	......	......
P$\underline{4}$, greatest anteroposterior diameter	20.5	20.8	23.5	......
P$\underline{4}$, transverse diameter across protocone	15.8	15.8	17.1	......
M$\underline{1}$, greatest anteroposterior diameter	25.2	25.4	25	26.3
M$\underline{1}$, greatest transverse diameter	22.8	23.2	24	24.9
M$\underline{2}$, greatest anteroposterior diameter	36.5	25.9	37.3	35.8
M$\underline{2}$, greatest transverse diameter	22.9	23.3	23.6	23.7
M$\underline{2}$, anteroposterior diameter of heel from metacone to end	13.7	15.3	14	......

	No. Z 6.	No. Z 7.	No. Z 8.	No. Z 9.	No. Z 10.	No. Z 19.	No. Z 53.	No. Z 52.
Length from anterior side $\bar{C}$ to posterior side of M$\bar{3}$	......	.....	......	......	.....	.....	......	.....
Length from posterior side $\bar{C}$ to anterior side of M$\bar{1}$	......	.....	......	......	.....	.....	49.5	.....
Length from anterior side M$\bar{1}$ to posterior side of M$\bar{3}$	......	.....	81	*a*81	82	.....	84	84
$\bar{C}$, anteroposterior diameter at base of enamel	*a*27	.....	*a*27	......	.....	.....	30.7	.....
P$\bar{4}$, anteroposterior diameter	......	.....	13.5	......	.....	13.8	13.2	.....
P$\bar{4}$, transverse diameter	......	.....	7.2	......	.....	8.5	17.2	.....
M$\bar{1}$, anteroposterior diameter	35	31.3	32.4	32	31.7	32.4	33.5	32
M$\bar{1}$, transverse diameter across protoconid	16.6	15.1	16	15.5	14.5	16.2	15.3	15.6
M$\bar{1}$, width of heel	18	16.7	16.7	17	17.2	17.2	17.5	16.5
M$\bar{2}$, anteroposterior diameter	31.7	30.2	30.8	30.4	30.4	31.4	28	29.1
M$\bar{2}$, transverse diameter across protoconid	22.4	21	21.4	21.6	20.8	21.6	21.8	21.3
M$\bar{3}$, anteroposterior diameter	......	21.4	21.3	21.8	21.9	.....	22.1	22.6
M$\bar{3}$, transverse diameter across protonoid	......	17	17.2	17	16.9	.....	17.6	17.8

a. Approximate.

Axial Skeleton

Skull.—The skull of *Arctotherium* from Potter Creek Cave described by Cope and the complete specimen (plate 2) from the same locality, now in the collection of the University of California, are distinctly smaller than the skull of *A. yukonense.* Most of the skull materials from Rancho La Brea resemble more in size *A. simum* than *A. yukonense.* One specimen, No. Z 5, L. A. M., unfortunately poorly preserved, belonged apparently to a very large male individual, approaching in size the type described by Lambe.

In the proportions of the skull *Arctotherium* resembles *Tremarctos.* The skull is not as wide across the zygomatic arches (plate 3, fig. 1) as in the large brown bears of Alaska. In *Arctotherium* the snout is distinctly broader and the cranium is noticeably wider across the postorbital processes and at the postorbital constriction than in *U. sheldoni.* The external nares, contrasted with those of *Ursus,* are relatively large and their greatest width is situated above the middle of the opening, giving it a true cordate cross-section. In *Ursus* the greatest diameter is nearer the base of the opening, and the outline is not distinctly cordate. The nasal bones are short and broad, the transverse diameter of the nasals taken together and at their anterior end equaling considerably more than half their length. The superior process of the premaxillary is usually short and blunt, more as in *Tremarctos* than in *Ursus.* The dorsal surface of the frontal behind the postorbital processes is not sharply demarcated laterally by temporal crests. The frontal region is gently convex transversely except for a slight median concavity. Viewed from the side, the frontal vaults higher above the orbits than in either *U. sheldoni* or in *Tremarctos* and the dorsal contour does not drop so abruptly to the muzzle as in the former. The orbit is comparable in size to that in the large brown bears, but is directed laterally rather more than in these forms. The position of the orbit in *Tremarctos* is more like that in *Ursus.*

The parietal region is not materially different from that of *Ursus,* except possibly in the nature of the parietal foramina, of which there are on each side, in skull 3001 U. C. C., a large lower foramen near the parietal-squamosal suture and a smaller one just below the point of union of the sagittal and lambdoidal crests. In skull Z 1 L. A. M. Coll. from Rancho La Brea, the two foramina, comparable to those in the Potter Creek Cave specimen, are present only on the right side. In No. Z 1 the smaller foramen is situated lower than in No. 3001. A sagittal crest is formed by the parietals. The lambdoidal crest possesses a simple convex curve from the median line to the squamosal. A thin median longitudinal crest is present on the occiput (plate 4, fig. 2). The foramen magnum is larger than in *Ursus sheldoni* and it is oval in shape, with greatest diameter transverse. The paroccipital process is thin toward the base and comes to a blunt point somewhat as in *Tremarctos*. The lower end is almost of even length with the mastoid process. In *Ursus* the process is thicker and does not descend nearly so far as the mastoid process. The paroccipital process is not so far removed from the condyle in *Arctotherium* as in *Ursus*. While the mastoid process in *Arctotherium* is heavy, it is not as prominently developed as in *Ursus*. The process possesses, however, more individuality than in *Tremarctos*.

The tympanic forms a small but distinct bulla (plate 3, fig. 2). This structure is apparently better developed than in *Tremarctos*. In *Ursus* the tympanic is flattened. Laterally the tympanic is drawn out into a process between the mastoid and the postglenoid processes as in *Tremarctos*. The condylar foramen is relatively small and is situated close to the inner base of the paroccipital process and to the foramen lacerum posterius. No tuberosity is formed where basioccipital and tympanic meet as in *Ursus*.

Behind the pterygoid the alisphenoid continues the lateral wall of the posterior narial opening and the postero-inferior margin ascends directly to the front and to the outer side of the eustachian canal and the foramen lacerum medius. The foramen ovale seems to be situated slightly closer to the foramen lacerum medius than in *Ursus*. An alisphenoid canal is present. The foramen rotundum lies within the recess of the alisphenoid canal. Close to the anterior opening of this canal is situated the foramen lacerum anterius as in the skull of *Tremarctos;* in *Ursus* the two openings are farther apart.

The lateral wall of the frontal behind the postorbital process projects considerably beyond that forming the floor of the orbit and its border extends downward and backward from the process, defining the grooves that lodge nerves and blood-vessels to the eye.

The foramen transmitting a branch of the trigeminal nerve and blood-vessels to the interior of the nose is much larger than in the

Alaskan brown bears, while the posterior opening of the palatine canal is quite small. There are two external infraorbital openings which are quite widely separated and lead into canals that are distinct to the orbital face of the maxillary. In the type specimen of *Arctotherium simum* three facial exits are present. In *Tremarctos* and in *Ursus* only a single facial exit occurs.

The post-narial notch is farther behind the tooth rows in *Arctotherium* (plate 3, fig. 2) than in either *Tremarctos* or in *U. sheldoni.* The palate is absolutely and relatively wider than in *Ursus.* The post-palatine foramina are situated about opposite the front end of M$\underline{2}$; in *Tremarctos* they are slightly farther forward, while in *Ursus* they are situated about opposite the hypocone in M$\underline{2}$. The grooves running forward from these foramina seem less distinct than in *Ursus.* The farthest point forward in median line reached by the maxillo-palatine suture is nearly opposite the middle of M$\underline{1}$, in which respect *Arctotherium* resembles *Tremarctos,* while in *Ursus* the suture forms a ∧ with the apex reaching a point opposite the posterior cusp of P$\underline{4}$.

Three anterior palatine openings are present, but the medial opening is much larger than in *Ursus, Arctotherium* resembling *Tremarctos* in this character.

Mandible.—A very marked characteristic of the ramus of the mandible of *Arctotherium* (plate 4, fig. 3) is the presence of a double masseteric fossa, the two depressions being separated by a sharp, oblique ridge extending from the anterior base of the coronoid process to the posterior inferior margin.[8] The upper fossa has about the area and depth of that in *Ursus americanus* and is very little smaller than that of *Arctotherium bonaerense.* The anterior or lower depression is very deep and may extend forward to a point below the middle of M$\overline{2}$. At the lower margin where the fossa comes very close to the inferior border of the jaw it may have a depth of 15 mm. or more. A double masseteric fossa occurs in other species of arctotheres and in *Tremarctos,* but is absent in *Ursus.* In the mandible of *Hyaenarctos punjabiensis,* figured by Lydekker (1884, pl. 31, fig. 1), the region posterior to M$\overline{3}$ is not well preserved. There is, however, no indication of a fossa extending along the horizontal ramus below the posterior molar teeth, as in the Pleistocene genus.

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[8] Ameghino (1902, p. 228), in the description of the species *Arctotherium wingei,* states that the masseteric fossa is simple, but the evidence of his figures is not entirely clear on this point.

In the fragmentary ramus of *Agriotherium* (*Hyaenarctos*) *schneideri* (Sellards, E. H., 1916, pl. 12), from the Bone Valley formation (Upper Miocene or Lower Pliocene) of Florida, there occurs a type of masseteric fossa comparable, apparently, to that in *Arctotherium.* The region posterior to M$\overline{3}$ is also broken away in this specimen, but a noticeable depression is present in the horizontal ramus lying for the most part beneath M$\overline{3}$. There seems good reason for believing that this fossa is equivalent to the lower depression in *Arctotherium.*

Several jaws have been found in Potter Creek Cave, in which the coronoid process is preserved. This process is broad at the base and at its upper end projects backward as a sharp process, as in *Tremarctos.* While the horizontal ramus is large and heavy, it by no means reaches the dimensions seen in *Agriotherium* (*Hyaenarctos*) from the Tertiary of Florida. In the rami of *Arctotherium* from Rancho La Brea two mental foramina have been noted. The anterior foramen is the larger and is situated below the posterior end of P$\overline{4}$, while the posterior foramen is below the middle of M$\overline{1}$. In specimen 3001 U. C. C., from Potter Creek Cave, a small foramen is situated below the protoconid of M$\overline{1}$, a larger foramen below the front end of P$\overline{4}$, and a still larger foramen between and below the alveoli for P$\overline{3}$ and P$\overline{2}$. In *Agriotherium* (*Hyaenarctos*) *schneideri* the largest of the mental foramina is situated below the posterior end of P$\overline{4}$. Several smaller foramina are apparently present below the anterior premolars. In *Tremarctos* the anterior foramen is below P$\overline{3}$, while the small posterior foramen is below the posterior root of M$\overline{1}$.

Vertebrae.—The number of vertebrae of *Arctotherium simum* found in Potter Creek Cave is small, as is the case with most of the mammalian forms occurring in this deposit. Several cervical and dorsal vertebrae, found on or near the surface by Richardson, during one of his early visits to the cave, are the property of the U. S. National Museum and have been kindly loaned for study. The collections of the Los Angeles Museum contain dorsal and lumbar vertebrae belonging to *A. californicum*, but unfortunately many of these lack epiphyses and are poorly preserved. It is impossible at present to give the number of vertebrae of the dorsal, lumbar, and caudal regions, but the presumption is that the number is similar to that of the closely allied *Tremarctos.* In a member of the latter

TABLE 4

Comparative Measurements (in Millimeters) of Skulls of Arctotherium simum and A. californicum

	Arctotherium simum from Potter Creek Cave, No. 3001, U. C. Coll.	Arctotherium californicum from Rancho La Brea, No. Z 1, L. A. M. Coll.
Cranium		
Length, anterior end of premaxillary to inion	391	418.2
Length, anterior end of premaxillary to posterior end of condyle	...	387.4
Length, anterior end of premaxillary to inferior notch between condyles	...	362.8
Length, anterior end of premaxillary to anterior border of posterior nasal opening	...	210.5
Length, from posterior end of glenoid cavity to posterior end of condyle	...	111.9
Length, anterior side of premaxillary to posterior side of auditory meatus	300	323.4
Length, from postorbital process of frontal to inion	220	244.8
Length, from anterior border of premaxillary to anterior side of orbit	110	132
Length, from anterior border of orbit to posterior side of auditory meatus	192	189
Greatest width across muzzle from outer walls of canine alveoli	101.5	106.8
Width across frontal at narrowest point between orbits	112	126
Greatest width across postorbital processes	*a*150	154
Least width of postorbital constriction	...	100
Greatest width across zygomatic arches	...	247.6
Greatest width across mastoid processes	*a*167	185.7
Greatest diameter across condyles	...	77
Palate, width between middle internal borders of $M\underline{1}$	80	71
Width of nasals anteriorly	47	...
Length of nasals	81	...
Width of anterior nares	77	76.4
Height of anterior nares	63	...
Height of orbit	50	50
Height, inferior border of maxillary to top of frontal between postorbital processes of frontal	121	143.4
Height of inion above superior border of auditory meatus	94	103.2
Height of inion above base of occipital condyles	...	119.8
Mandible		
Length from posterior side of condyle to anterior alveolar border	262	...
Height at anterior end $M\overline{1}$	58.5	...
Height at anterior end $M\overline{3}$	75.4	...
Thickness below posterior end $M\overline{1}$	25.5	...

a. Approximate.

genus (No. 194309, U. S. Nat. Mus.) the vertebral formula is C 7, D 13, L 7, S 3, Ca 8 or 9.

In the atlas of *Arctotherium* (plate 6, figs. 1, 1*a*) the posterior opening of the vertebrarterial is on the upper side of the transverse process some distance in advance of the posterior margin, much as in the Canidae. In *Tremarctos* a somewhat similar position is to be noted for this opening. In *Ursus* the opening is on the upper side of the posterior face of the transverse process. In *Arctotherium* the posterior border of the transverse process is slightly notched, but the plates supporting the posterior articular faces for the axis are not so prominent as they may be in *Ursus*, and there is a very narrow posterior notch. The following gives in millimeters the measurements of the atlas of *Arctotherium simum* from Potter Creek Cave, No. 3035, University of California collection:

Greatest width across lateral processes	*a*177
Greatest transverse diameter across anterior articular faces	33.6
Least anteroposterior diameter of dorsal wall of neural canal	87.6
Greatest height of neural canal	39

a. Approximate.

The axis (plate 6, figs. 2, 2*a*) resembles that in *Tremarctos* and differs from that in *Ursus* in the following characters:

The relative size of the neural canal, the pointed odontoid process, and the depth of the neural spine in front of the pedicle of the arch.

The transverse process, although broken on each side of the single specimen available from Rancho La Brea, appears to have been short as in *Tremarctos*. The pedicle of the neural arch is narrow anteroposteriorly.

The following gives (in millimeters) the measurements of the axis of *A. californicum* from Rancho La Brea, No. Z 39, L. A. M. Coll.:

Transverse diameter across articulating surfaces for atlas	84.6
Greatest transverse width across postzygapophyses	64
Greatest length of neural spine	*a*80.7
Least anteroposterior diameter of pedicle of neural arch	22
Greatest length of vertebra from anterior end of odontoid process to posterior face of centrum	*a*82

a. Approximate.

In the cervical series from Potter Creek Cave (No. 2654, U. S. Nat. Mus.) the individual vertebrae are smaller than in the large Alaskan brown bear. The lateral processes are not well preserved. They appear to have been more slender than in *Ursus*. In these vertebrae the neural canal is large, the dorso-ventral diameter being greater than in the large brown bear.

TABLE 5

Measurements (in Millimeters) of Cervical Vertebrae, No. 2654, U. S. Nat. Mus.

	Cervical 3.	Cervical 4.	Cervical 5.	Cervical 6.	Cervical 7.
Length of centrum	36.6	37.8	37.3	35.9	33.9
Width of centrum between inner borders of vertebrarterial canals	36	40.8	42.1	43.5	....
Depth of centrum across posterior face	27.7	28.8	28.5	29	32
Greatest width across prezygapophyses	59.6	*a*68	70	....	74.4

a. Approximate.

A sacrum (No. Z 113, L. A. M. Coll.) of *A. californicum* is shown in plate 6, figures 9, 9*a*. In this specimen 3 sacral vertebrae are present. The posterior end is broken. The neural spines are distinct and all were presumably more prominent than in *Ursus*. The sacral foramina are larger than in the latter genus. The measurements of sacrum follow, in millimeters:

Greatest length (approx.)	145
Greatest width of anterior end (approx.)	130
Width across anterior articulating processes	56.3

Appendicular Skeleton

Scapula.—This element (plate 7, figs. 1, 1*a*) is a trifle narrower and longer than in the Alaskan brown bear, *Ursus sheldoni*, and seems to approach in its proportions the scapula in *Tremarctos*. The anterior border, in its extent from the upper third to the coracoid region, has uniform curve as in *Tremarctos*. In *U. sheldoni* the anterior and inferior borders are demarcated by a sharp angle. The antero-inferior region of the prescapular fossa seems also to be bent more to the inner side in this form than in either *Arctotherium* or in *Tremarctos*. The posterior border in the upper half is carried back considerably as in *Tremarctos* and in *Ursus*. The acromion resembles that in *Tremarctos*. The end of the process does not curve inward as in *Ursus*. In front and at the base of the spine, about 80 mm. above the glenoid fossa, is a foramen, while on the opposite side of the spine are two larger foramina. These foramina are distinctly larger than in *U. sheldoni* and have a somewhat different position.

No distinct articulating facet is present in either *Arctotherium* or in *Tremarctos* on the posterior side of the spine near the base and along the inferior border as in *Ursus sheldoni.*

TABLE 6

MEASUREMENTS (IN MILLIMETERS) OF SCAPULA

	A. californicum, Rancho La Brea, No. Z 30, L. A. M. Coll.
Length, measured from glenoid articulation to dorsal border along axis of spine	331
Greatest width taken normal to anterior border	252
Greatest anteroposterior diameter of inferior extremity	95.2
Transverse diameter of glenoid articulation to outer side of acromion	119.5

Humerus.—The upper arm bone (plate 7, figs. 2, 2*a*, 3, 3*a*) is considerably longer than that of the large brown bear and may equal or exceed in length the humerus of the Pliocene *Indarctos? oregonensis.* Specimens of the humerus of *Arctotherium* from Potter Creek Cave and from Rancho La Brea are decidedly more slender than that of the Pliocene form. At the proximal end the groove between the head and the greater tuberosity is not so deep as in *Ursus.* The greater tuberosity does not have a deep excavation on the outer surface as in *Ursus.* The bicipital groove is wider and shallower than in *Ursus,* resembling the groove in the humerus of *Tremarctos.*

The proximal half of the shaft does not flatten transversely and widen anteroposteriorly relatively so much as in *Felis atrox* or in *Smilodon.* The deltoid ridge is not prominent, nor is the supinator ridge so conspicuous as in *Ursus.*

Arctotherium resembles *Indarctos? oregonensis* and *Tremarctos,* and differs from *Ursus,* in the presence of an entepicondylar foramen in the humerus. The bar inclosing the opening is more slender than in the large Pleistocene Felidae from Rancho La Brea.

Ulna.—The ulna (plate 8, figs. 1 and 2) is decidedly longer than that in the large brown bear and in the Pleistocene *Felis atrox.* When the bone is oriented so that the coronoid process is directed anteriorly, the plane of the olecranon process is seen to be widely removed from the principal longitudinal plane of the shaft. This

TABLE 7

Measurements (in Millimeters) of Humerus

	A. simum, Potter Creek Cave.		A. californicum, Rancho La Brea.		
	No. 3001, U. C. C.	No. 3039, U. C. C.	No. Z 30, L. A. M. C.	No. Z 77, L. A. M. C.	No. 20085, U. C. C.
Greatest length	447.8	445.7	497	....	446.3
Greatest anteroposterior diameter of proximal end measured from anterior end of greater tuberosity	110	....	118.5	....	107.6
Greatest width of proximal end	91.9	90	97.3	....	95.2
Transverse diameter of shaft at middle	41.2	40.9	43.5	46.4	42.4
Anteroposterior diameter of shaft at middle	46.2	48.7	53	60	48.8
Greatest width at distal end	123.2	....	126.8	156	126.7
Greatest width of distal articulation	90.2	91.6	97	116.4	92.8

TABLE 8

Measurements of Ulna (in Millimeters)

	A. simum, Potter Creek Cave.		A. californicum, Rancho La Brea.		
	No. 3426, U. C. Coll.	No. 3145, U. C. Coll.	No. Z 30, L. A. M. Coll.	No. Z 32, L. A. M. Coll.	No. 20088, U. C. Coll.
Greatest length	445.8	421.2	471	*a*475	433.5
Greatest width of olecranon process	79.3	71.5	84	....	*a*66
Width from posterior border to tip of coronoid process	71	83.6	85.4	....	75.3
Least distance from sigmoid notch to posterior border	41.5	46	46.7	....	39.6
Greatest diameter of distal end	46.8	50.4	....	....	46

a. Approximate.

divergence, seen also in *Ursus* and in *Tremarctos*, is much greater than that in the ulna of *Felis atrox* or of *Smilodon*. Also in *Arctotherium*, as in other ursids, the articulating surface for the humerus, situated at the upper end of the sigmoid notch and on the radial side of the ulna, reaches much nearer to the proximal border of the olecranon than in the ulna of either of the large Pleistocene felids from Rancho La Brea. The process forming the proximal end of the sigmoid notch is much more slender than in *Felis atrox* or in *Smilodon*.

The posterior border of the ulna is rounded, in which respect

Arctotherium is more like *Tremarctos* than like *Ursus*. A continuous articulating surface is present for the radius as in *Tremarctos*, not divided as in *Ursus*. At the distal extremity the radial facet is relatively much smaller than in *Ursus*. The distal end of the shaft in No. Z 30 is slender, relatively more so than in *Ursus*. In a second specimen from Rancho La Brea (No. Z 32) this part of the shaft is much heavier.

Radius.—This fore-arm bone (plate 8, figs. 3, 3*a*, and 3*b*) resembles rather closely in shape the corresponding limb element in *Tremarctos*. The proximal extremity appears to be more as in *Tremarctos* than in *Ursus*. The shaft at the middle is not so heavy as in *Ursus*.

TABLE 9

MEASUREMENTS OF RADIUS (IN MILLIMETERS)

	A. simum, Potter Creek Cave.		A. californicum, Rancho La Brea No. Z 32 L. A. M. Coll.
	No. 10262 U. C. Coll.	No. 3427 U. C. Coll.	
Greatest length	374.5	389.3	....
Greatest diameter of proximal extremity	52.4	56.3	63
Width of shaft at middle	31.4	37.3	35
Thickness of shaft at middle	19	24	22
Greatest diameter of distal extremity	*a*59	73.6	....

a. Approximate.

Carpus.—The scaphoid-lunar of *Arctotherium* presents in anterior view (plate 8, fig. 4*a*) a much deeper surface than that of *Ursus*. The postero-internal process is less massive than in the latter form. On the distal side (plate 8, fig. 4), the articulating surface for trapezium and trapezoid is less extensive than in *Ursus* and indicates perhaps that the first metacarpal was less divergent in *Arctotherium* than in *Ursus*.

The most striking difference between *Arctotherium* and *Ursus* in the appearance of the cuneiform (plate 8, figs. 6, 6*a*) is the greater transverse extent of this element in the former genus. *Arctotherium* resembles *Tremarctos* in this respect. The ulnar articulating surface appears flatter than in *Ursus*.

In the unciform (plate 8, figs. 5, 5*a*) the lower forward end of the lateral articulating surface for cuneiform is carried on a distinct process, well shown in anterior view. The upper posterior portion of this surface is apparently not so extensive as in *Ursus.* The distal articulation for metacarpals IV and V does not show the disparity between anteroposterior and transverse diameters seen in *Ursus.*

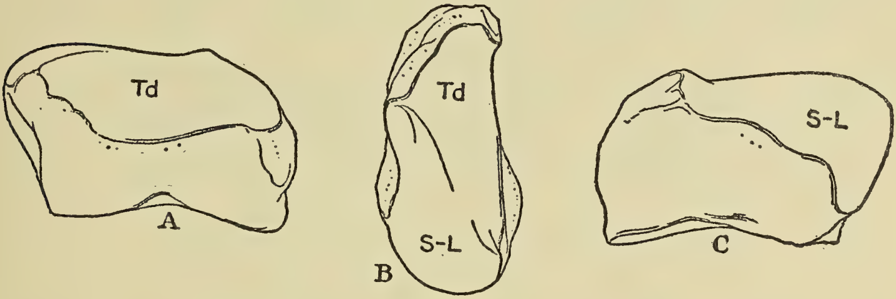


FIG. 2. *Arctotherium californicum* Merriam. Trapezium, No. 24252, U. C. C., ×1. A, view of trapezoid surface (Td); B, inner view, surface for scaphoid-lunar (S–L); C, view of surface for scaphoid-lunar.

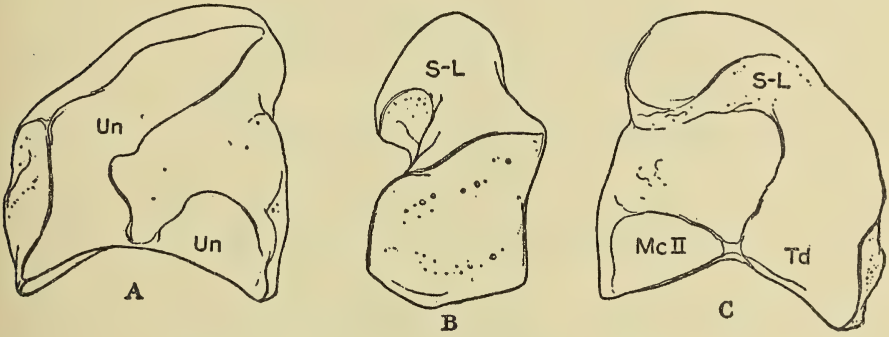


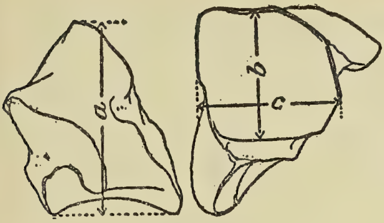
FIG. 3. *Arctotherium californicum* Merriam. Magnum, No. Z 106, L. A. M. C. ×1. A, outer view, surfaces for unciform (Un); B, anterior view, surface for scaphoid-lunar (S–L); C, inner view, trapezoid surface (Td); surface for metacarpal II (McII).

The trapezium (figs. 2) is long and rather narrow. Posteriorly it is heavier than in *Ursus.* The articulating surface for the scaphoid-lunar (S-L) is noticeably less extensive than in *Ursus.* The surface for the trapezoid (Td) is, however, rather large. An inner view (fig. 2*b*) shows these surfaces not so sharply separated as in *Ursus*. The surface for metacarpal I is long and narrow. In the pisiform (fig. 4) the posterior process is more compressed than in *Ursus*.

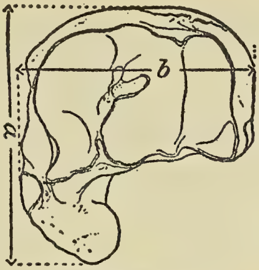
TABLE 10

Measurements of Carpal Elements of Arctotherium simum, Potter Creek Cave, and Arctotherium californicum, Rancho La Brea

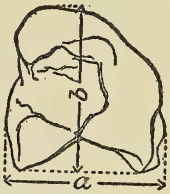
Species.	Collection and No.	Description.	Millimeters.
		Scaphoid-lunar:	
A. simum.	U. C. 5975	Greatest anteroposterior diameter (*a*-axis)	56.3
Do	U. C. 5975	Greatest transverse diameter (*b*-axis)	56
Do	U. C. 24253	Greatest anteroposterior diameter (*a*-axis)	71.6
Do	U. C. 24253	Greatest transverse diameter (*b*-axis)	71.8
A. calif.	L. A. M. Z 105	Greatest anteroposterior diameter (*a*-axis)	58.7
Do	L. A. M. Z 105	Greatest transverse diameter (*b*-axis)	57.5
Do	L. A. M. Z 108	Greatest anteroposterior diameter (*a*-axis)	....
Do	L. A. M. Z 108	Greatest transverse diameter (*b*-axis)	73
Do	L. A. M. Z 109	Greatest anteroposterior diameter (*a*-axis)	59.4
Do	L. A. M. Z 109	Greatest transverse diameter (*b*-axis)	57.7
Do	L. A. M. Z 135	Greatest anteroposterior diameter (*a*-axis)	62.2
Do	L. A. M. Z 135	Greatest transverse diameter (*b*-axis)	62.5
		Cuneiform:	
Do	L. A. M. Z 47	Anteroposterior diameter	43
Do	L. A. M. Z 47	Greatest transverse diameter	58
Do	L. A. M. Z 107	Anteroposterior diameter	42.8
Do	L. A. M. Z 107	Greatest transverse diameter	52.2
		Unciform:	
Do	U. C. 24067	Proximo-distal diameter (*a*-axis)	47.6
Do	U. C. 24067	Anteroposterior diameter of distal articulating surface (*b*-axis)	34.7
Do	U. C. 24067	Transverse diameter of distal end (*c*-axis)	36.5
Do	L. A. M. Z 45	Proximo-distal diameter (*a*-axis)	50.8
Do	L. A. M. Z 45	Anteroposterior diameter of distal articulating surface (*b*-axis)	38.5
Do	L. A. M. Z 45	Transverse diameter of distal end (*c*-axis)	39.7
		Magnum:	
Do	L. A. M. Z 133	Greatest anteroposterior diameter (*a*-axis)	40.7
Do	L. A. M. Z 133	Greatest proximo-distal diameter (*b*-axis)	40.4
Do	L. A. M. Z 106	Greatest anteroposterior diameter (*a*-axis)	36
Do	L. A. M. Z 106	Greatest proximo-distal diameter (*b*-axis)	35
		Trapezium:	
Do	U. C. 24252	Length	38.2
Do	U. C. 24252	Depth	22.7
Do	U. C. 24252	Width	18
		Pisiform:	
Do	L. A. M. Z 110	Length	49.6
Do	L. A. M. Z 110	Greatest diameter of articulating end	31.5



Unciform.



Scaphoid-lunar.



Magnum.

Metacarpus.—A number of metacarpals of *Arctotherium* (plate 8, figs. 7 to 10) are available from Rancho La Brea and from Potter Creek Cave. The specimens from Rancho La Brea are generally larger than those from the cave deposit. Difference in age was considered (Merriam, 1911) in the original description of *A. californicum.* Merriam also stated that a single metapodial in the University of California collections from the asphalt deposits resembles in form and in dimensions the corresponding bone of *A. simum* from Potter Creek Cave. The latter specimen, No. 21004, is a third metacarpal and in a comparison with another median metacarpal from the asphalt beds shows clearly the range in size which characterizes the arctotheres of the Rancho La Brea fauna.

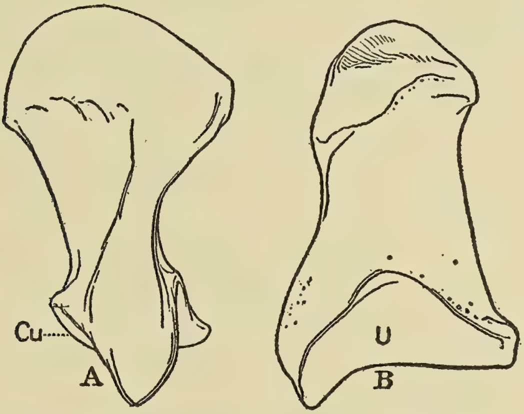


Fig. 4. *Arctotherium californicum* Merriam. Pisiform, No. Z 110, L. A. M. C. ×1. A external view, cuneiform surface (Cu); B, view of ulnar side, surface for ulna (U).

Metacarpal I in *Arctotherium* (plate 8, fig. 7) is relatively short in contrast to metacarpals II to V and is absolutely shorter than the corresponding element in *Ursus*. The shaft is relatively slender. At the proximal end of the median metacarpal the anterior articulating surface for metacarpal IV is more extensive than in *Ursus*. The anterior face of the proximal end is somewhat excavated. At the proximal end of metacarpal V the articulating surface for the unciform is broader transversely and the lateral process does not appear to be so rugose as in *Ursus*.

TABLE 11

Measurements of Metacarpals (in Millimeters)

A. simum, Potter Creek Cave, No. 3040, U. C. Coll.	I	II	III	IV	V
Greatest length	72.6	96.8	104	106.2	104
Anteroposterior diameter of proximal end	24.2	30	31.6	31	32.3
Least width of shaft	10.8	13.4	14	15.8	16.1
Greatest width at distal end	19.5	23.3	26.5	25.7	25.5

A. californicum, Rancho La Brea, No. 17754, U. C. Coll.	I	III	IV	V
Greatest length	86.8	126.7	130.5	130.2
Anteroposterior diameter of proximal end	29.8	39.3	41.7	43.5
Least width of shaft	13.9	18.7	23	21
Greatest width of distal end	25.7	29.9	34	34

A. californicum, Rancho La Brea	12768 U. C. Coll. I	Z 93 L. A. M. Coll. I	14816 U. C. Coll. II	21004 U. C. Coll. III	Z 124 L. A. M. Coll. IV	Z 117 L. A. M. Coll. V
Greatest length	75.7	81.5	114.3	107.6	123	128.3
Anteroposterior diameter of proximal end	23.5	24.8	36.5	33.3	36.9	38.1
Least width of shaft	10.6	11.6	18.6	14.6	18.6	20.8
Greatest width of distal end	19	21.2	29.4	24.8	29.7	32.6

Pelvis.—The pelvis of *Arctotherium* (plate 9, figs. 1 and 2) is represented only by fragmentary materials, including, however, all the principal parts. The ilium appears to be relatively shorter than in *Tremarctos*. The outer end is narrowed more than in *Ursus*. The neck of the ilium immediately in front of the acetabulum is wide as in *Tremarctos*. The pubis in No. Z 48 L. A. M. Coll. is relatively narrower than in either *Ursus* or in *Tremarctos*. The obturator foramen in this specimen is not so wide dorsoventrally as in *Ursus*.

Femur.—The thigh bone of *Arctotherium* (plate 9, figs. 3, 4, 4*a*) possesses a relatively slender shaft, and the lower end is rather broad with anterior face more rounded than in *Ursus*. The lower, inner border of the shaft, above the inner condyle, does not form a sharp ridge. At the proximal end the digital fossa is smaller than in *Ursus* and the lesser trochanter is slightly higher than in the latter genus. At the distal end the patellar surface does not extend upward so far as in *Ursus* and the inner condyle does not reach distinctly below the distal surface of the outer condyle. The latter character suggests, perhaps, that the distal end of the femur in *Arctotherium* was not turned inward as far as in *Ursus*.

TABLE 12

Measurements of Pelvis of A. californicum, Rancho La Brea (in Millimeters)

	Z 51 L. A. M. Coll.	Z 50 L. A. M. Coll.	Z 48 L. A. M. Coll.
Ilium, length from rim of acetabulum to anterior border	*a*185	....	....
Ilium, greatest width	*a*175	....	....
Ilium, least width of neck in front of acetabulum	65	*a*78	....
Acetabulum, transverse diameter	....	87	....
Obturator foramen, greatest anteroposterior diameter	....	....	90.3
Obturator foramen, greatest dorsoventral diameter	....	....	58.3

a. Approximate.

TABLE 13

Measurements of Femur (in Millimeters)

	A. simum, Potter Creek Cave, No. 10211, U. C. Coll.	A. californicum, Rancho La Brea, No. 20082, U. C. Coll.
Greatest length	513.5	501.8
Greatest transverse width of proximal end taken at right angles to long axis of shaft	....	127
Anteroposterior diameter of head	61	62.2
Transverse diameter of shaft at middle	*a*44.5	41.6
Anteroposterior diameter of shaft at middle	*a*37.2	32.9
Greatest width of distal end	110.4	108.5
Greatest anteroposterior diameter of distal end	83	84.6

a. Approximate.

Tibia.—When viewed from the front the shaft of the tibia (plate 10, fig. 1) shows slightly more curvature in longitudinal extent than in *Ursus*, thus resembling that in *Tremarctos*. Above the cnemial crest the anterior border of the dorsal surface is deeply notched. This notch is, however, not so wide as in *Ursus*; it is inconspicuous in the tibia of *Tremarctos* under observation. On the posterior side of the tibia (plate 10, fig. 3) the two lines marking the attachment of the flexor digitorum muscle, and extending from the base of the outer articulation of the proximal end obliquely toward the inner side, are much farther apart than in *Ursus*, *Arctotherium* resembling *Tremarctos* in this respect. The outer line is quite distinct in its extent along the posterior face and may be traced to the distal end.

Another specimen (No. Z 76, L. A. M. Coll.) from Rancho La Brea lacks the proximal and distal epiphyses. It is heavier than the element described above.

TABLE 14

MEASUREMENTS OF PATELLA (IN MILLIMETERS)

	Arctotherium californicum, Rancho La Brea.	
	No. Z 97 L. A. M. Coll.	No. Z 98 L. A. M. Coll.
Greatest length	72.2	80
Greatest width	59	69.3
Anteroposterior diameter through middle of femoral surface	31	38

TABLE 15

MEASUREMENTS OF TIBIA (IN MILLIMETERS)

	Arctotherium simum, Potter Creek Cave.		A. californicum, Rancho La Brea.	
	No. 3034 U. C. Coll.	No. 3724 U. C. Coll.	No. Z 31 L. A. M. Coll.	No. Z 76 L. A. M. Coll.
Total length measured along inner side	359	*a*387.6	404	....
Greatest width of proximal end	106.6	110.1	110.7	....
Transverse diameter of shaft at middle	34.4	37	40.7	43
Anteroposterior diameter of shaft at middle	37.7	41.8	41.6	45.6
Greatest transverse diameter of distal end	87.1	85.6	88.4	....
Greatest anteroposterior diameter of distal end	47.4	*a*51	52	....

a. Approximate.

Tarsus.—In the calcaneum (plate 10, figs. 4, 4*a*) the posterior process appears to be relatively narrower in transverse diameter than in *Ursus*. The outer facet for the astragalus is flatter, while the inner facet is supported by a process more pointed than in *Ursus*.

Several astragali of *Arctotherium* (plate 10, figs. 5, 5*a*) are available from Rancho La Brea and from Potter Creek Cave. Specimens from the asphalt beds show some variation in size. The smallest specimen in the Rancho La Brea collection is distinctly larger than that of *Ursus*. No astragalar foramen is present. In *Arctotherium* the outer calcaneal facet is relatively narrow. There appears to be less disparity in size between outer and inner calcaneal facets than in *Ursus*.

In the cuboid of *Arctotherium* the obliquity of the proximal surface for the calcaneum varies somewhat. On the inner side of the cuboid and along the proximal two-thirds are the three articulating surfaces, all connected, for astragalus, navicular, and ectocuneiform. A small facet situated on the inner side and along the distal margin, and separated from the proximal surfaces, articulates also with the ectocuneiform. In the cuboid of the Pliocene *Indarctos? oregonensis* the large proximal facet for the ectocuneiform is discrete. The transverse ridge on the plantar surface of the cuboid of *Arctotherium* is quite prominently developed.

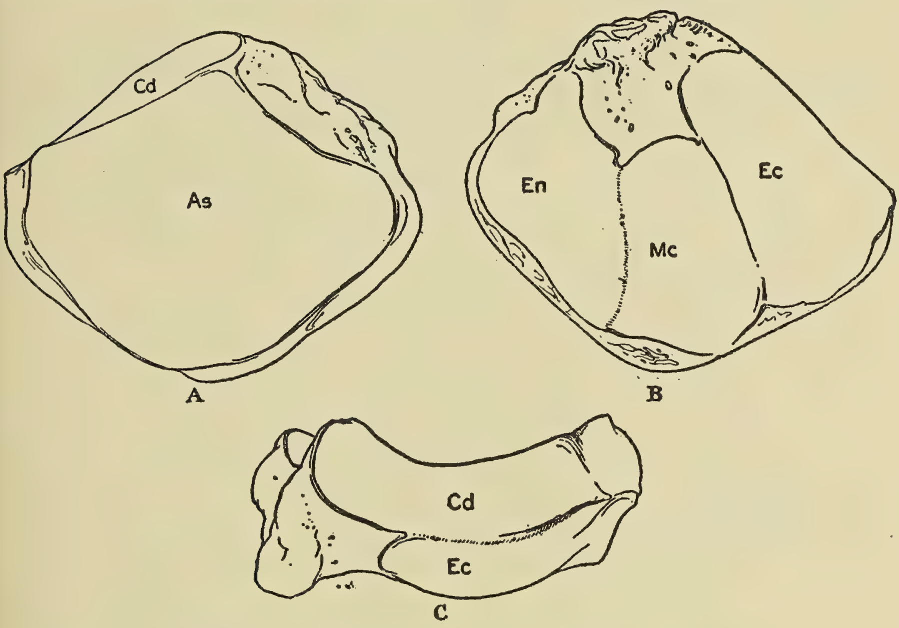


FIG. 5. *Arctotherium californicum* Merriam. Navicular, No. Z 100, L. A. M. C. ×1. A, view of astragalar surface (As), cuboid surface (Cd); B, view of cuneiform surfaces, entocuneiform surface (En), mesocuneiform surface (Mc), ectocuneiform surface (Ec); C, outer view.

In the navicular (fig. 5) a distinct process is developed on the distal side posterior to the cuneiform surfaces. This process is more pronounced than in *Ursus*.

In the ectocuneiform both the articulating surfaces for the navicular and for metatarsal I are concave in anteroposterior direction. The surface for the metapodial is slightly wider transversely, but is shorter in anteroposterior diameter than the surface for the navicular. The upper posterior extremity of the ectocuneiform forms a larger tuberosity than in *Ursus*.

TABLE 16

MEASUREMENTS (IN MILLIMETERS) OF TARSAL ELEMENTS OF ARCTOTHERIUM SIMUM FROM POTTER CREEK CAVE, UNIVERSITY OF CALIFORNIA COLLECTION, AND A. CALIFORNICUM FROM RANCHO LA BREA, LOS ANGELES MUSEUM COLLECTION

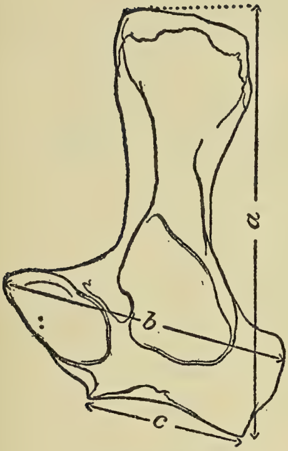
Calcaneum.	A. simum, No. 10214.	A. californicum, Rancho La Brea.			
		No. Z 81.	No. Z 84.	No. Z 83.	No. Z 114.
Greatest length (*a*-axis)	110	*a*116.5	*a*115.6	*a*127	111.5
Greatest width measured obliquely across sustentaculum (*b*-axis)	77.8	85.6	86.7	87.2	75.8
Width of cuboid facet (*c*-axis)	39.4	45.8	48.5	50.7	41.8

Astragalus.	A. simum, No. 10215.	A. californicum.				
		No. Z 112.	No. Z 111.	No. Z 96.	No. Z 94.	No. Z 115.
Greatest length (*a*-axis)	65.8	79	78	82.8	67.8	73
Greatest width (*b*-axis)	72.6	86.2	80.4	87.4	72.5	79.3
Least distance across neck (*c*-axis).	40	48.2	44.3	*b*50.3	41.6	43.2

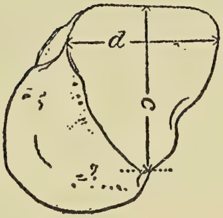
Cuboid.	A. simum, No. 4311.	A. californicum.		
		No. Z 103.	No. Z 104.	No. Z 134.
Greatest anteroposterior diameter (*a*-axis)	*b*46	63.7	53	60.9
Greatest proximo-distal diameter (*b*-axis)	34.3	42.1	35.9	41
Length of metatarsal facet (*c*-axis)	33.3	42	37	42.7
Width of metatarsal facet (*d*-axis)	29.2	38	30.8	38.7

Navicular.	A. californicum.		Ectocuneiform.	A. californicum. No. Z 43.
	No. Z 95.	No. Z 100.		
Anteroposterior diameter (*a*-axis)	55.4	58.8	Greatest proximo-distal diameter (*a*-axis)	22.7
Transverse diameter (*b*-axis)	43.5	47.5	Anteroposterior diameter (*b*-axis)	37

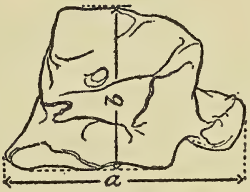
a. This measurement does not include the epiphysis at the end of the tuber calcis.
b. Approximate.



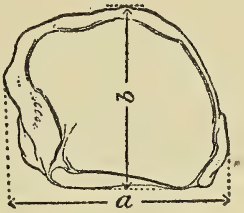
Calcaneum.



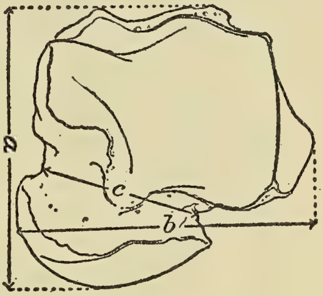
Cuboid.



Cuboid.



Navicular.



Astragalus.

Metatarsus.—The first metapodial in the pes (plate 10, fig. 6) is relatively short in contrast to that in *Ursus.* The shaft in metatarsal III increases slightly in width from the proximal third to the distal extremity. The posterior facet on the outer side of the proximal end in this metapodial is directed less proximally than in *Ursus.* In the fourth metatarsal the two articulating facets on the outer side of the proximal end are sometimes separated rather widely. On the inner side of the proximal end the forward facet is concave as in *Ursus.* The posterior facet shows division into two parts, the lower for metatarsal III and the upper part for the ectocuneiform. In the fifth metatarsal the lateral process of the proximal end is prominent, but is relatively not so deep dorso-ventrally as in that of *Ursus.*

Phalanges.—A number of phalanges of *Arctotherium* have been found at Potter Creek Cave and at Rancho La Brea. Several specimens, presumably of *Arctotherium*, from the asphalt deposits are shown on plate 10, figures 9 to 14. The terminal phalanges have the claw-core shortened, in which respect *Arctotherium* differs from *Ursus.*

TABLE 17

MEASUREMENTS (IN MILLIMETERS) OF METATARSALS OF ARCTOTHERIUM CALIFORNICUM FROM RANCHO LA BREA, LOS ANGELES MUSEUM COLLECTION, AND UNIVERSITY OF CALIFORNIA COLLECTION

Metatarsal.	Collection and No.	Greatest length.	Antero-posterior diameter of proximal end.	Least width of shaft.	Greatest width of distal end.
I	Z 102 L. A. M.	75.2	32	12	21.3
I	Z 101 L. A. M.	73.2	27.7	10.8	18.3
II	Z 40 L. A. M.	101.3	36.8	16.3	24.8
III	Z 99 L. A. M.	106.3	37.8	16	23.2
III	Z 90 L. A. M.	121.2	41.8	20.8	30.5
IV	Z 99 L. A. M.	115.7	38	17.4	25.2
IV	Z 88 L. A. M.	....	40.6	19.8	....
V	Z 99 L. A. M.	115.8	37	15.6	24.5
V	Z 85 L. A. M.	*a*129	....	19.8	30.8
V	No. 24251 U. C. Coll.	110	39.8	13.8	24.3

a. Approximate.

TABLE 18

MEASUREMENTS OF PHALANGES OF A. CALIFORNICUM FROM RANCHO LA BREA, LOS ANGELES MUSEUM COLLECTION

Phal. No.	Mus. No.	Measurements.	Millimeters.
I	Z 130	Greatest length	64.4
I	Z 130	Greatest width of proximal end	34.7
I	Z 137	Greatest length	56.9
I	Z 137	Greatest width of proximal end	34.8
II	Z 138	Greatest length	33.1
II	Z 138	Greatest width of proximal end	21.5
II	Z 138	Depth of proximal end	18.4
II	Z 139	Greatest length	34.4
II	Z 139	Greatest width of proximal end	22
II	Z 139	Depth of proximal end	18.2
III	Z 140	Length	35.5
III	Z 140	Greatest depth of proximal end	26.5
III	Z 141	Length	39.4
III	Z 141	Greatest depth of proximal end	28.7

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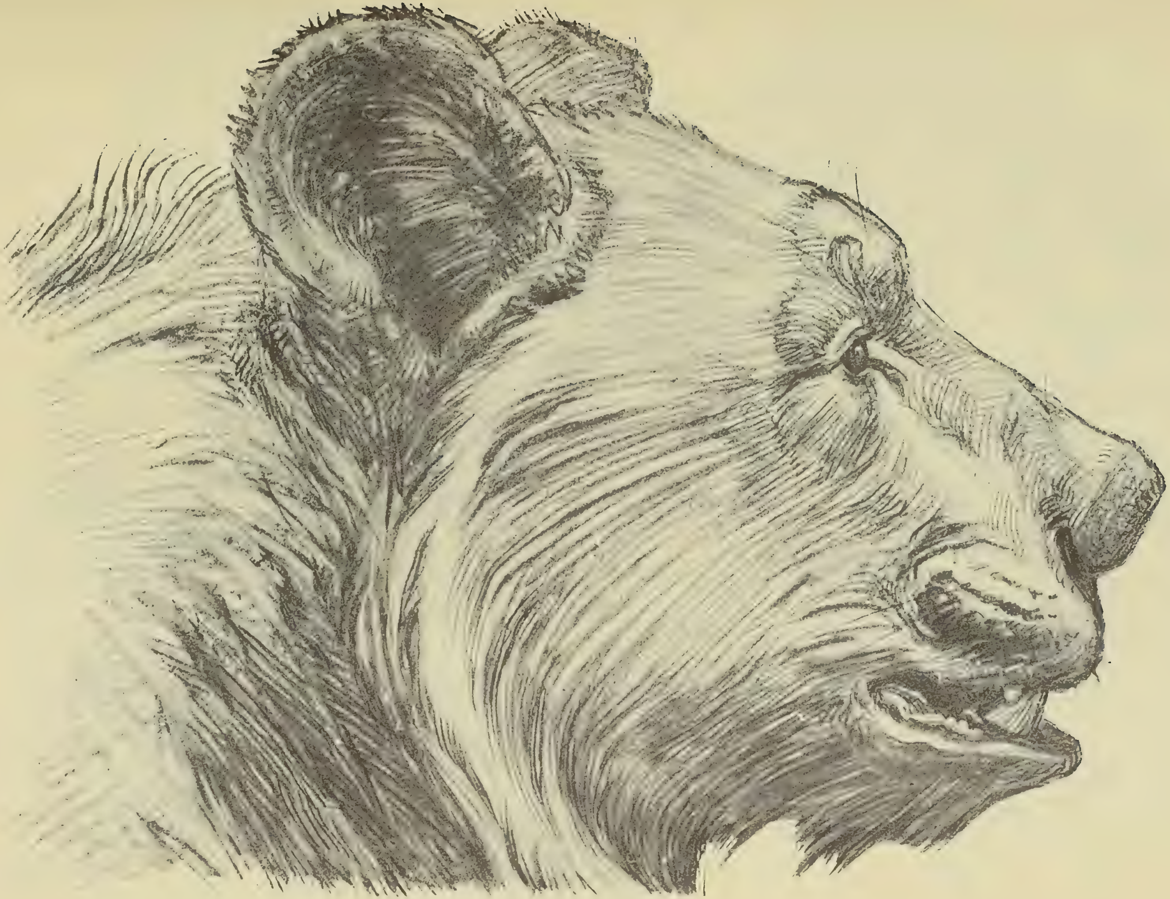
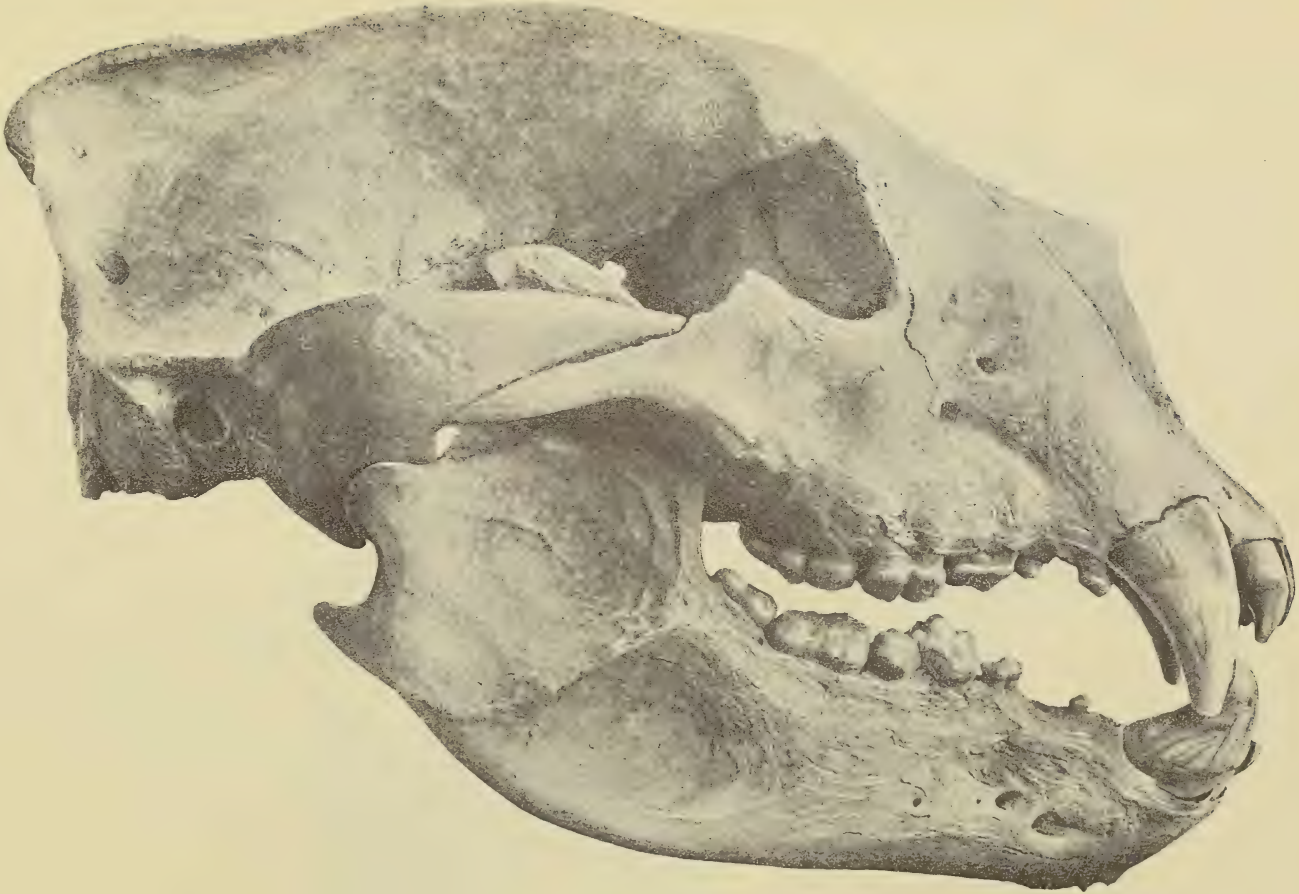
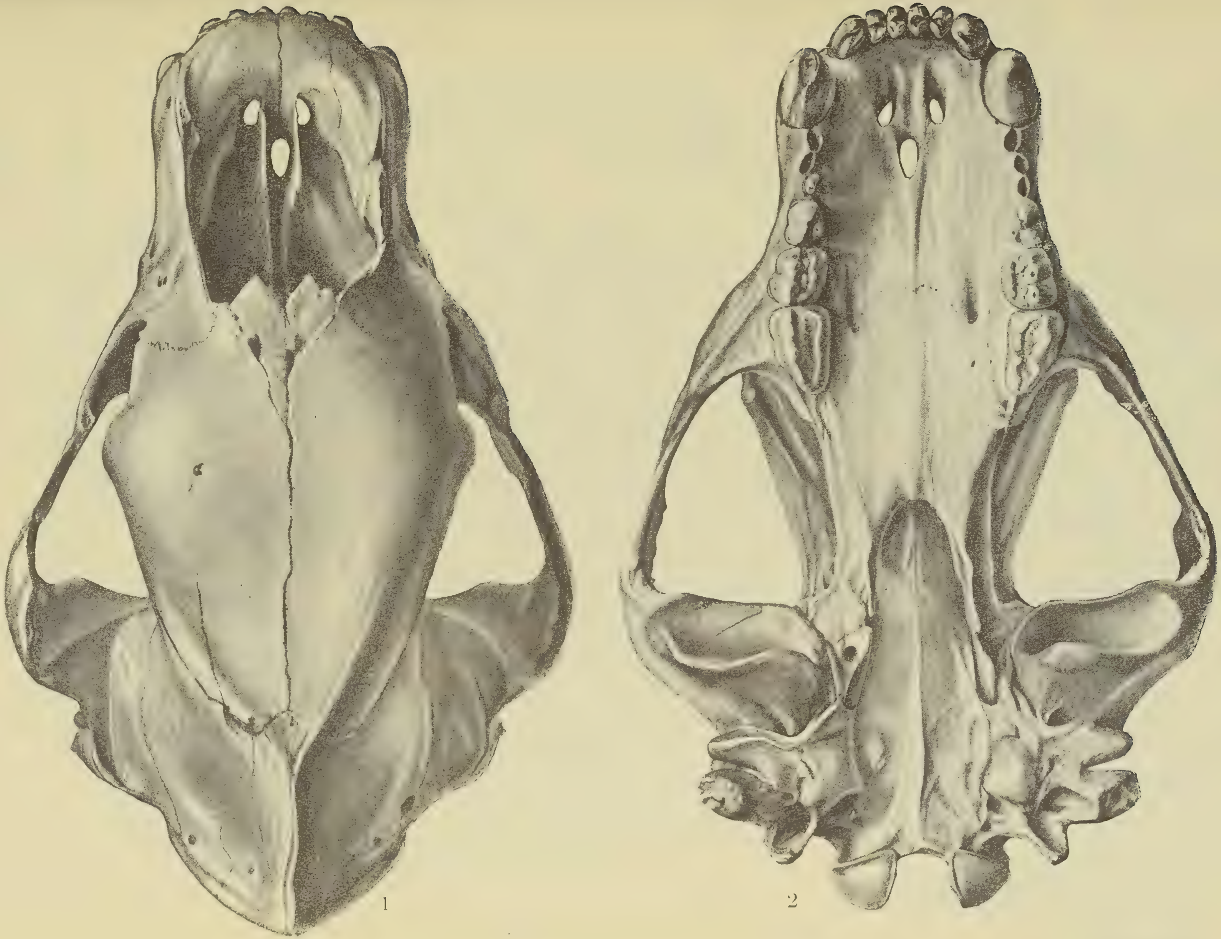


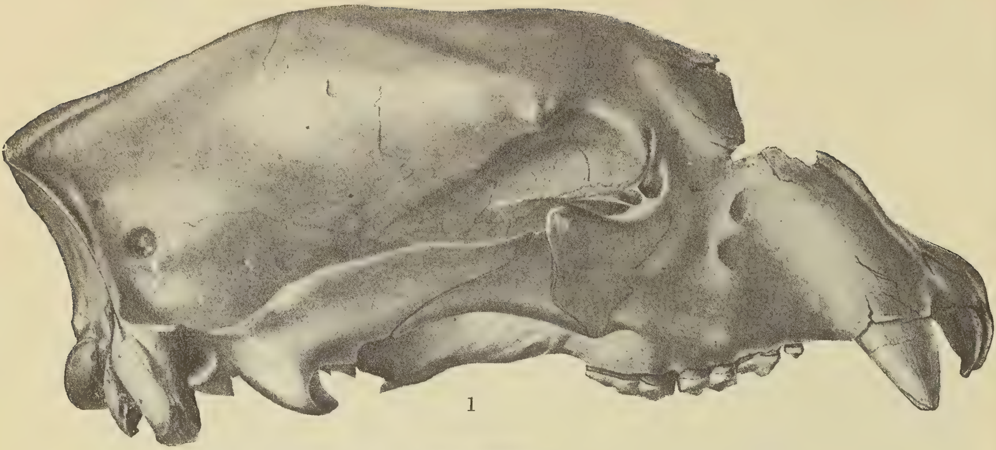
Arctotherium simum Cope. Restoration of head by Charles R. Knight under direction of John C. Merriam and Chester Stock.



Arctotherium simum Cope. Skull and mandible, No. 3001, lateral view, approx. × 0.45. University of California Collections, Potter Creek Cave.



Arctotherium californicum Merriam. 1 and 2, skull, No. Z 1, superior and inferior views, × 0.3. Los Angeles Museum Collections. Rancho La Brea Beds.



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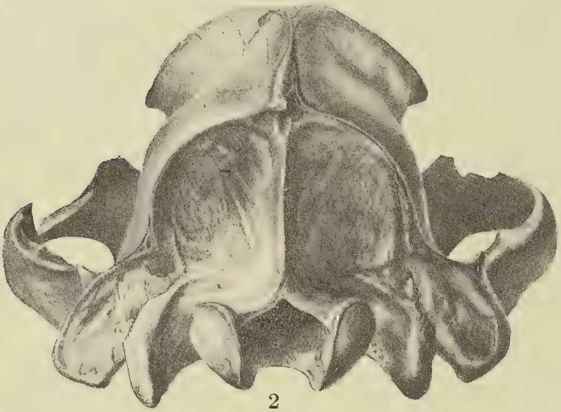

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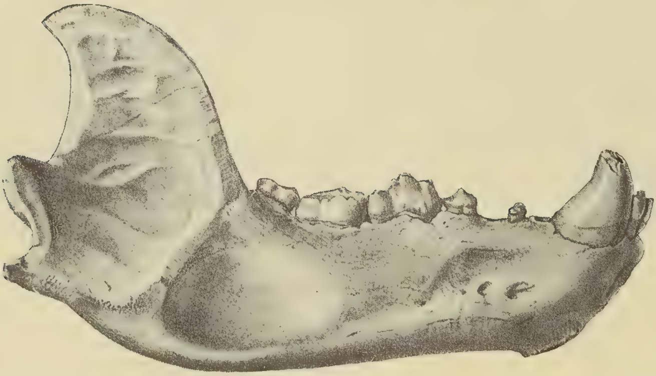
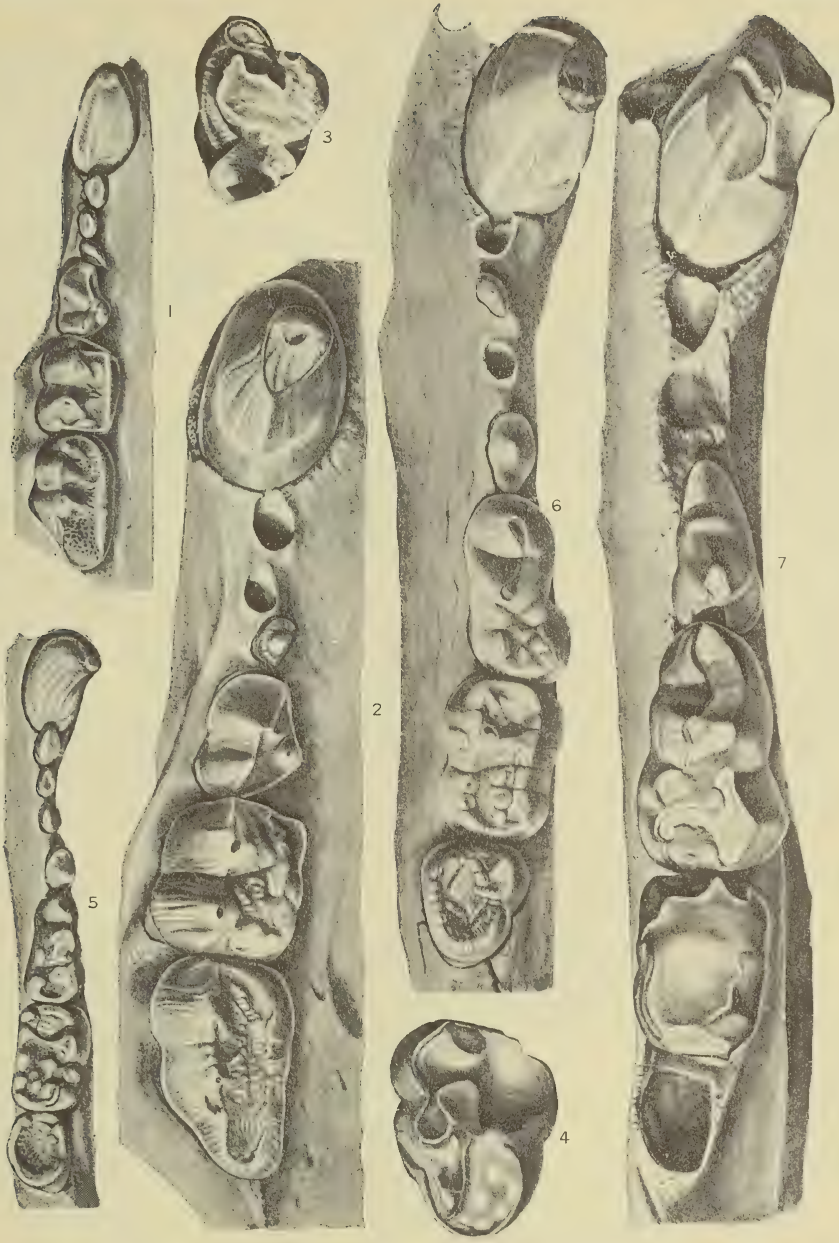


3

1 and 2. *Arctotherium californicum* Merriam. Skull No. Z 1, lateral and posterior views, × 0.3. Los Angeles Museum Collections, Rancho La Brea Beds.

3. *Arctotherium simum* Cope. Mandible, No. 3001, lateral view, × 0.3. University of California Collections, Potter Creek Cave.



1. *Tremarctos ornatus* (Cuvier). Superior dentition, No. 171011, U. S. Nat. Mus. Recent, South America.

2. *Arctotherium californicum* Merriam. Superior dentition, No. Z 1, L. A. M. C. Pleistocene, California.

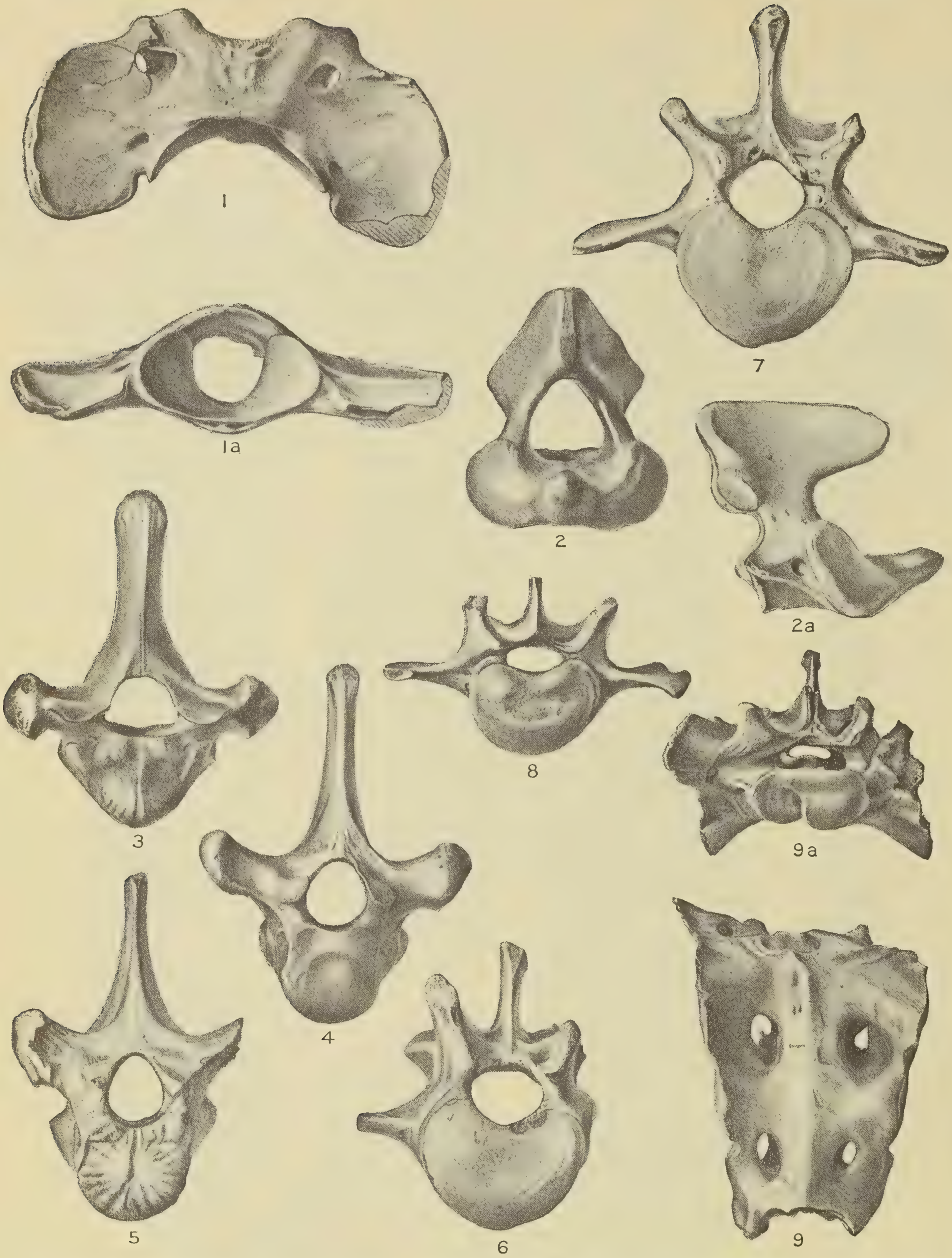
3 and 4. *Indarctos? oregonensis* Merriam, Stock, and Moody. P$\underline{4}$, and M$\underline{2}$, No. 22362, U. C. C. Pliocene, Oregon.

5. *Tremarctos ornatus* (Cuvier). Inferior dentition, No. 171011, U. S. Nat. Mus. Recent, South America.

6. *Arctotherium simum* Cope. Inferior dentition, No. 3001, U. C. C. Pleistocene, California.

7. *Agriotherium* (*Hyaenarctos*) *schneideri* Sellards. Inferior dentition, No. 6856, Fla. Surv. Coll. Pliocene, Florida.

All figures are occlusal views, × 0.8 (approximate)



1 and 1*a*. *Arctotherium simum* Cope. Atlas, No. 3035, superior and posterior views, × 0.3. University of California Collections, Potter Creek Cave.

2 and 2*a*. *Arctotherium californicum* Merriam. Axis, No. Z 39, anterior and lateral views, × 0.3.

3. Second dorsal vertebra, No. Z 33, anterior view, × 0.3.

4. Third dorsal vertebra, No. Z 34, anterior view, × 0.3.

5. Dorsal vertebra, No. Z 35, anterior view, × 0.3.

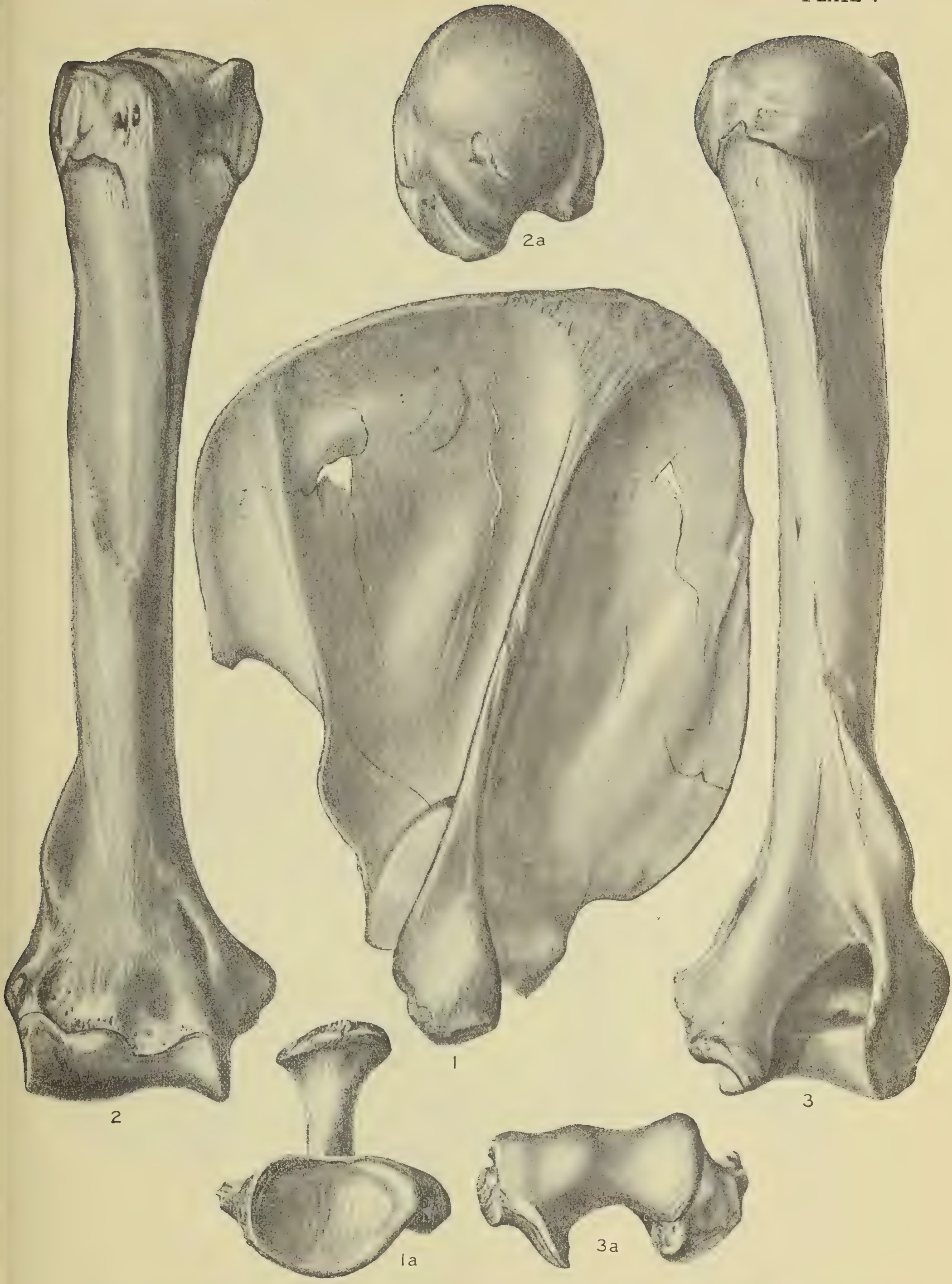
6. Last dorsal vertebra, No. Z 36, anterior view, × 0.3.

7. Anterior lumbar vertebra, No. Z 37, anterior view, × 0.3.

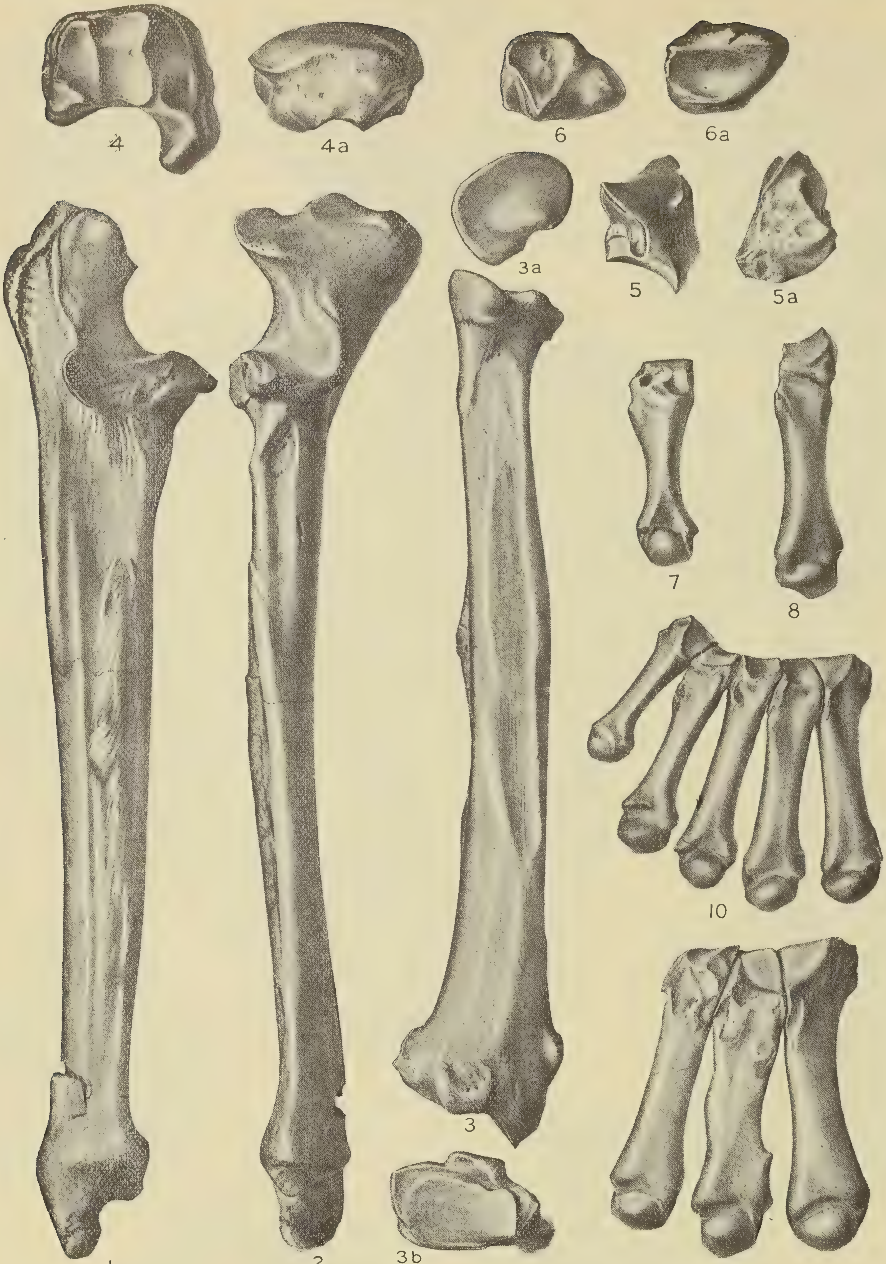
8. Posterior lumbar vertebra, No. Z 38, anterior view, × 0.3.

9 and 9*a*. Sacrum, No. Z 113, inferior and anterior views, × 0.3.

Figs. 2 to 9*a* are of specimens in the Los Angeles Museum Collections, Rancho La Brea Beds.



Arctotherium californicum Merriam. Los Angeles Museum Collections. Rancho La Brea Beds.
1 and 1*a*. Scapula, No. Z 30, views of outer side and of glenoid articulation, × 0.3.
2 and 2*a*. Humerus, No. Z 30, anterior and proximal views, × 0.3.
3 and 3*a*. Humerus, No. Z 30, posterior and distal views, × 0.3.



Arctotherium californicum Merriam:

1 and 2. L. A. M. Ulna, No. Z 30, radial and inner views.

4 and 4*a*. Univ. Cal. Scaphoid-lunar, No. 24253, inferior and anterior views.

5 and 5*a*. Univ. Cal. Unciform No. 24067, inner and anterior views.

6 and 6*a*. L. A. M. Cuneiform, No. Z 107, inferior and superior views.

7. Univ. Cal. Metacarpal 1, No. 17751, anterior view.

8. Univ. Cal. Metacarpal 2, No. 14816, anterior view.

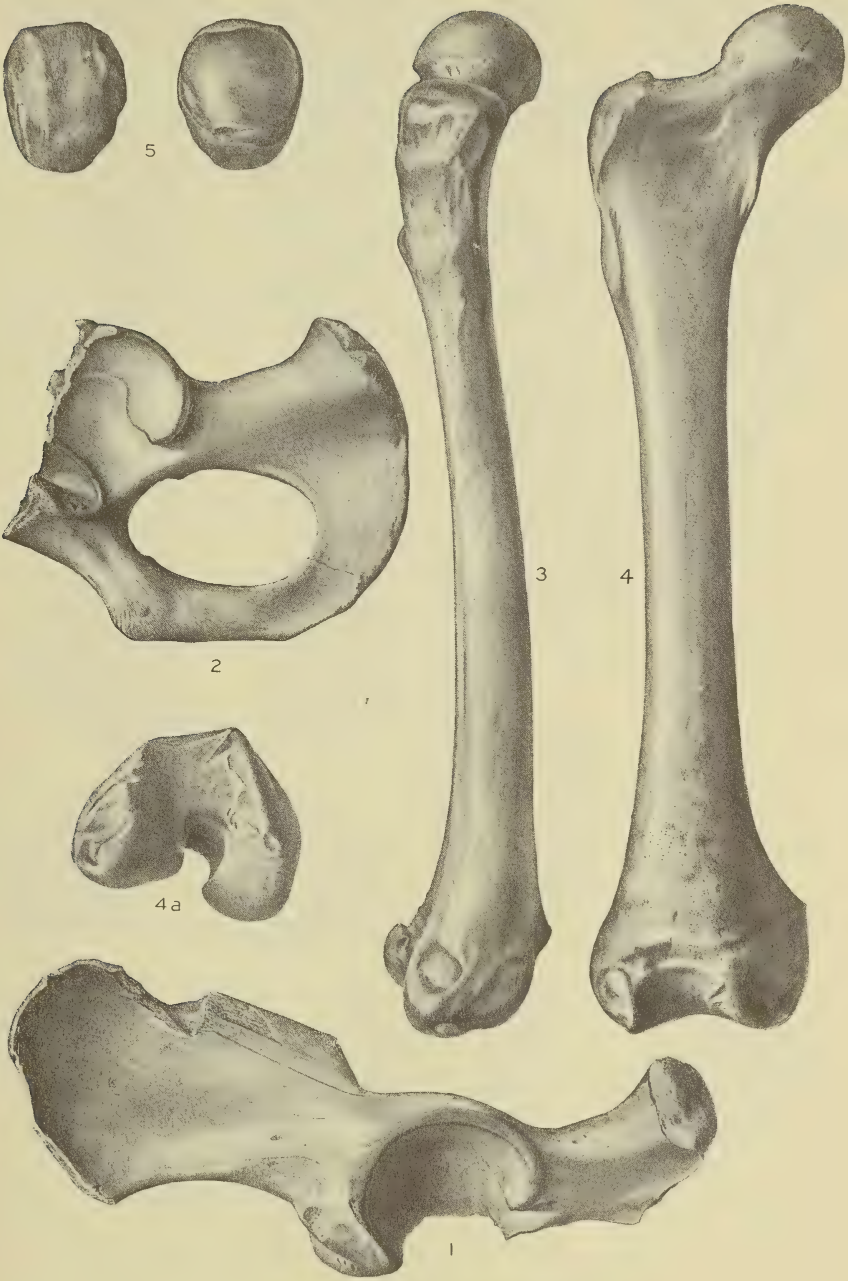
9. Univ. Cal. Metacarpals 3, 4, and 5, No. 17755, anterior view.

Arctotherium simum Cope:

3, 3*a*, and 3*b*. Univ. Cal. Radius, No. 3427, lateral, proximal, and distal views.

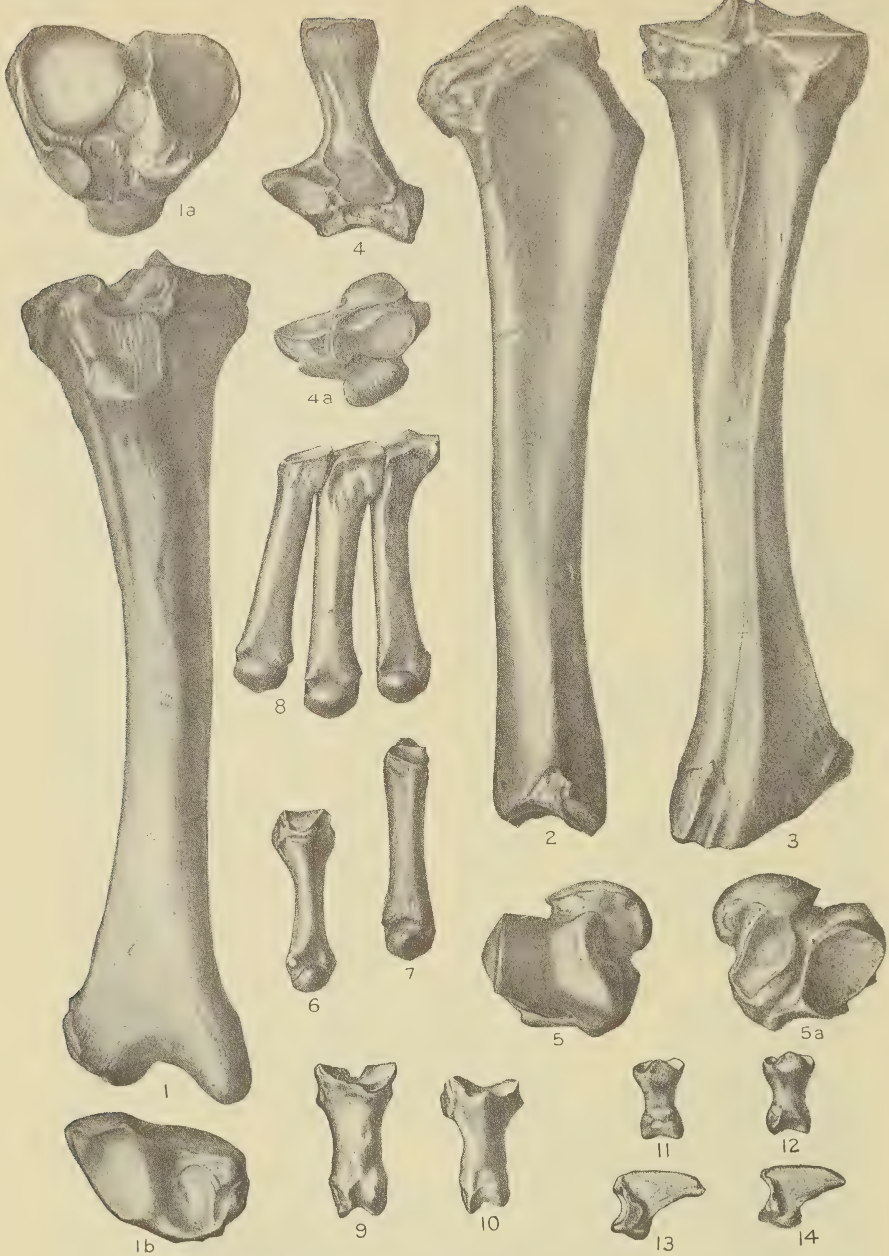
10. Univ. Cal. Metacarpus, No. 3040, anterior view.

All figures three-tenths natural size. Figs. 3, 3*a*, 3*b*, and 10 from Potter Creek Cave; all others from Rancho La Brea Beds.



Arctotherium californicum Merriam

1 and 2. Innominate bones, Nos. Z 49 and Z 48, lateral views, × 0.285 (approximate).
3. Femur, No. 20082, lateral view, × 0.285 (approximate).
4 and 4*a*. Femur, No. 20082, anterior and distal views, × 0.285 (approximate).
5. Patella, No. Z 97, anterior and posterior views, × 0.285 (approximate).
Los Angeles Museum Collections. Rancho La Brea Beds.



Arctotherium californicum Merriam. Los Angeles Museum Collections. Rancho La Brea Beds.

1, 1*a*, and 1*b*. Tibia, No. Z 31, anterior, proximal, and distal views, × 0.27.
2. Tibia, No. Z 31, lateral view, × 0.27.
3. Tibia, No. Z 31, posterior view, × 0.27.
4 and 4*a*. Calcaneum, No. Z 114, superior and anterior views, × 0.27.
5 and 5*a*. Astragalus, No. Z 94, superior and inferior views, × 0.27.
6. Metatarsal 1, No. Z 102, anterior view, × 0.3.
7. Metatarsal 2, No. Z 40, anterior view, × 0.27.
8. Metatarsals 3, 4, and 5, No. Z 99, anterior view, × 0.3.
9 and 10. First phalanges, Nos. Z 130 and Z 137, superior views, × 0.3.
11 and 12. Second phalanges, Nos. Z 139 and Z 138, superior views, × 0.3.
13 and 14. Third phalanges, Nos. Z 141 and Z 140, lateral views, × 0.3.

TERTIARY MAMMALS FROM THE AURIFEROUS GRAVELS NEAR COLUMBIA, CALIFORNIA

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INTRODUCTION

Since their earliest exploitation for gold, the auriferous gravels of the Sierra Nevada have yielded on occasion remains of fossil mammals whose age clearly indicates the presence of deposits belonging to several divisions of the Cenozoic. Extensive hydraulic and placer mining in this region is largely responsible for the fact that many localities where fossil materials have been found in the past are now no longer accessible.

In the course of mining operations by the Springfield Development Company, two horse teeth and a fragmentary camel jaw were found in gravels and sands of the Springfield shafts Nos. 2 and 3, located one and one-half miles southwest of Columbia, California. The mammalian remains were obtained by R. W. Chaney from J. S. Cademartori, Superintendent of the Springfield Development Company.

Since the stratigraphic occurrence of the material, as determined by Professor George D. Louderback, is definitely established with reference to the Tertiary section exposed in this region, interest attaches to the age and correlation of the deposits as suggested by the relationships of the fossil mammals. Moreover, the presence of fossil plants in the sedimentary series offers, among other features, an opportunity to check the age relationships of the accumulations by the application of paleobotanical evidence.

By John C. Merriam and Chester Stock. *Carnegie Institution of Washington Publication No. 440*, paper I, pp. 1–6, November 15, 1933.

Description of Vertebrate Remains

Hipparion, near mohavense Merriam

The two horse teeth available from the Springfield shaft Number 2, Univ. Calif. Coll. Loc. A 729, represent P$\underline{4}$ and M$\underline{3}$. The premolar, No. 24246 Univ. Calif. Coll. and the molar, No. 24247, were found some distance apart. In the light of the characters presented by these teeth there seems little reason for assuming that the specimens do not belong to the same species. Possibly two individuals are represented, differing slightly in age and size. These teeth resemble each other in the strongly developed external styles, in narrowness of the fossettes and complexity of their enamel borders, and in the flattened and somewhat elongate protocone.

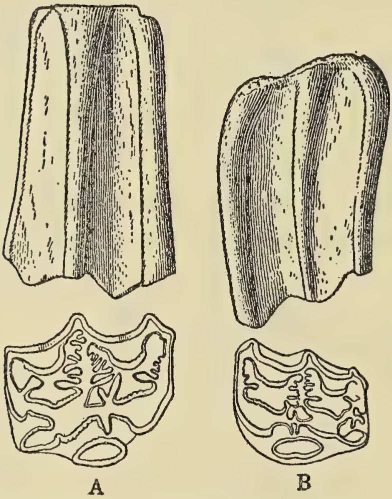

Fig. 1. *Hipparion*, near *mohavense* Merriam. A, P$\underline{4}$, No. 24246; B, M$\underline{3}$, No. 24247; lateral and occlusal views; × 1. University of California Collections. Auriferous sands and gravels, near Columbia, California.

Nos. 24246 and 24247 are smaller than comparable teeth of *Hipparion mohavense* from the Ricardo. They resemble, however, the latter in complexity of enamel borders of the fossettes. The protocone tends to flatten slightly, more so than in the typical *H. mohavense*. Likewise, in the more elongate character of this cusp, the teeth differ from the Ricardo type. However, the character of round-oval protocone seen in the type and associated teeth of

H. mohavense is modified somewhat in the subspecies *H. mohavense callodonte,* described also by Merriam from the Ricardo. In the characters in which *callodonte* differs from typical *mohavense* it approaches the specimens from Columbia.

In size Nos. 24246, 24247 resemble somewhat teeth of *Neohipparion gratum tehonense* described by Merriam from the Chanac formation of California. There is a more distinct tendency for the protocone to flatten in Nos. 24246, 24247 than in *N. gratum tehonense.* The fossettes may average slightly narrower than in teeth of *Neohipparion gratum* from the Snake Creek beds of Nebraska.

A single tooth described from the Siestan Pliocene of the Berkeley Hills, California,[1] No. 24241 Univ. Calif. Coll., and referred to *Hipparion,* near *mohavense,* shows considerable resemblance to the horse from the auriferous gravels. No. 24246 is slightly smaller than No. 24241, but similarity between the two teeth prevails in shape of protocone and in the degree of plication of the fossette borders. The plications seem to be essentially the same in both forms, but are slightly more numerous in No. 24246. While the plicaballin is single in the premolar, it is double in the third upper molar, No. 24247. In the Siestan tooth this structure is double with a small spur extending forward from the anterior plication.

Of the several specimens with which comparisons have been made, No. 24241 appears to resemble most closely the species recorded from near Columbia. Both Nos. 24241 and 24246, while not identical in character with teeth of typical *Hipparion mohavense,* resemble specimens belonging to this group of horses.

Measurements of Teeth (in Millimeters)

	$P\underline{4}$ No. 24246	M No. 24247
Greatest anteroposterior diameter	21.9	19
Transverse diameter across protocone and mesostyle	19.5	14
Anteroposterior diameter of protocone	6.8	6

Camelid, possibly Pliauchenia or Procamelus

Unfortunately the ramus of the mandible, No. 24248, is too fragmentary to give much information. The premolars and apparently the anterior molar have been broken away. The posterior molars are only partly preserved. This specimen came from shaft 3 (Richards shaft).

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[1] C. Stock, Univ. Calif. Publ. Bull. Dept. Geol. Sci., vol. 13, 19–21, 1 fig., 1921.

The specimen is larger than camel material referred to *Procamelus*, near *gracilis* from the Cedar Mountain upper Miocene, Nevada.

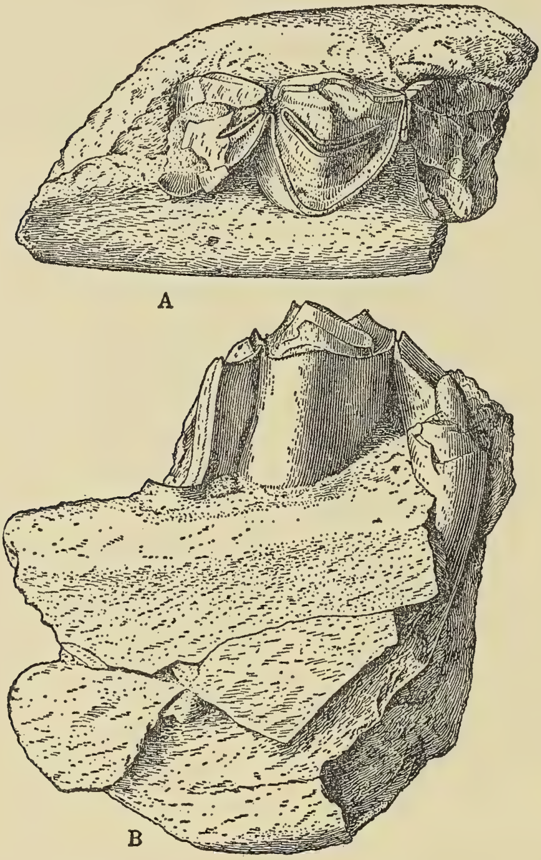

Fig. 2. Camelid, possibly *Pliauchenia* or *Procamelus*. A, B, fragment of jaw and lower dentition, No. 24248, dorsal and lateral views; × 1. Mass shown on upper side of figure 2A represents rock matrix. University of California Collections. Auriferous sands and gravels, near Columbia, California.

This is shown by the size of the ramus and the individual teeth. It is larger also than some of the materials referred tentatively to *Procamelus* or *Alticamelus* from the Ricardo lower Pliocene of the Mohave Desert.

AGE RELATIONSHIPS

The scattered vertebrate remains which have been found in the auriferous gravels and associated deposits of the Sierra Nevada, although for the most part fragmentary and incomplete, are suggestive of faunal stages ranging in age from late Oligocene or early Miocene to the Pleistocene.

Whatever age relationships are indicated by the mammalian remains from the gravels and sands exposed in the Springfield mine shafts near Columbia, the most direct evidence is that afforded by the horse teeth. The genus *Hipparion* representing this material is found elsewhere in western North America associated with faunas whose ages are distinctly later than that of the faunal elements recorded from early Tertiary beds in Calaveras County.[2] Moreover, nowhere in western North America is this genus of horse recorded in Pleistocene deposits. In stage of development the two teeth represent the *Hipparion* group as it is known in such horizons as the Ricardo deposits of the Mojave Desert region, three beds having been classed with the Pliocene. A close relationship is suggested with *Hipparion mohavense* and types compared with the latter.

Until cumulative information regarding the stratigraphic position of *Hipparion* in western Tertiary deposits is of such extent as to permit clear judgment, no definite statement can be made with reference to the lower time range of this genus. Recent discussions have emphasized the possible late Miocene appearance of *Hipparion* in America. Possibly the gravels and sands in which the horse teeth and camel jaw occurred near Columbia are upper Miocene in age.

[2] C. Stock, Proc. Nat. Acad. Sci., vol. 18, 552–553, 1932.

PALÆONTOLOGY AND HUMAN HISTORY

REVIEW OF "THE EOLITHIC PROBLEM—EVIDENCES OF A RUDE INDUSTRY ANTEDATING THE PALEOLITHIC," BY GEORGE GRANT MacCURDY

The Eolithic Problem—Evidences of a Rude Industry Antedating the Paleolithic. By George Grant MacCurdy.[1]

Within the last decades some of the principal questions regarding the Paleolithic stage in the evolution of man have come to be considered on a fair way to settlement, and the frontier of investigation in prehistoric anthropology has been pushed back into epochs representing the early Quaternary and the Tertiary. Some of the more important problems now under discussion concern the pre-Paleolithic or Eolithic stage and its culture. To these problems relating to the earliest culture of incipient man great interest attaches, and Dr. MacCurdy has materially assisted in making them understood in this country by presenting a clear and admirably constructed paper discussing the present stage of investigation in this field. He has taken the direct route to knowledge by visiting the original European localities and collections in company with investigators who have studied them, and his opinions are those of an unprejudiced observer with the original materials immediately before him. The paper includes an account of the early discoveries, special discussions of the finds in England and Belgium, a chronology of the stone age, and a very useful bibliography of the subject.

Technically, the Eolithic problem concerns the existence in Europe of implement-making and implement-using primates in periods antedating that of the Chellean or early Paleolithic industry. The time of the Chellean industry, or of the beginning of the Paleolithic, is not generally supposed to date back as far as the

Science, n. s., vol. 23, no. 591, pp. 659–661, April 27, 1906.

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[1] *American Anthropologist*, N. S., Vol. 7, pp. 425–479, with five half tone plates reproduced from photographs of eoliths, and six text figures illustrating the geological relations of implement-bearing beds.

beginning of Quaternary time. The industry of this epoch is commonly acknowledged to represent a grade of development in implement making too advanced to be considered as the first stage. The stage of Eolithic man represents the epoch of beginnings, in which the first use was made of primitive implements. It is described as commencing at least as early as Miocene time, and extending upward into the early Quaternary.

The industry of Puy-Courny in France represents the late Miocene; the industry of the Chalk Plateau in the south of England, so fully discussed by Prestwitch and others, is held to be Pliocene. Other industries of France and England are referred to the late Pliocene. The numerous occurrences in Belgium to which Rutot has devoted himself are early Quaternary.

In a study of the implement-like objects attributed to the work of primitive man-like forms living in the earlier divisions of the Eolithic epoch great difficulties are necessarily met. The first implements were evidently unmodified natural objects. If selected, they were chosen because their original form was more suitable for the purpose in view than that of other objects. The first artifacts were probably unintentionally chipped by use, and this class of objects grades into that showing intentional modification of form. The series leads then from the typical implement to the unmodified natural object, and considerably before the beginning is reached we arrive at a point where it is almost impossible to determine whether or not one is dealing with artifacts.

Having seen a little of the original localities and collections examined by Dr. MacCurdy, it has appeared to the writer that the Eolithic question is really rather sharply divided. The problem of the Belgian Eolithic flints of early Quaternary age seems hardly the same question as that relating to the Pliocene eoliths of the Chalk Plateau in England, or that of the French specimens from the Miocene of Puy-Courny. As is shown by Dr. MacCurdy, the Belgian Eolithic remains, to which he attaches the greatest importance, exhibit in many cases almost undeniable evidence of intentional modification by man. They belong moreover to a period not far antedating the industry of the Chellean epoch, and are not so far removed from the present but that a paleontologist might conceive of the type of primate which made them as existing up to the present day without radical physical changes. On the other hand, the age of the older deposits representing the earlier portion of the Eolithic epoch is so great, that to any one acquainted with the rapid changes of mammalian types in time, it is difficult to conceive of a form closely related to recent man as extending back to this period. The most that we could imagine would be that the place of man was occupied by some form not higher than the Javan *Pithecanthropus*, and possibly considerably lower than that type, and a question naturally arises as to whether a primate of this stage of evolution would or could make use of implements.

In the case of the eoliths of the Kent Plateau, Dr. MacCurdy has produced evidence which seems to favor intentional modification of form. On the other hand, M. Boule in a recent article[2] has figured and described most remarkable flint forms resembling eoliths, but produced by the impact on each other of numerous flints carried about in swiftly running water at a cement factory. In such a case as this, in which from the very nature of the problem the discrimination between natural and artificial becomes increasingly difficult, it would appear that other evidence must be called in before we can reach definite conclusions. Apparently the ultimate decision concerning many of the most important points relating to the very early history of man must be determined by purely paleontological observations upon his skeletal remains, and the European record of these is as yet practically a blank for the Eolithic epoch. We shall, however, always obtain a large part of our information concerning early man from studies of the industries which represent him.

In whatever way the question of European Pliocene and Miocene man is finally settled, the present discussion is furnishing the occasion for considerable contributions to our knowledge of the origin and distinctive characters of flaked flints both natural and artificial, and will lead to a much better understanding of this side of the problem. Certainly no possible line of investigation which can furnish us information concerning the earliest man-like types should be neglected. Whether or not we are willing to agree with the investigators in all their conclusions in this particular case, we must certainly commend the earnest and painstaking effort which is being made to come to a clear understanding regarding the significance of the interesting materials now under consideration.

[2] M. Boule, 'L'Origine des Eolithes,' *L'Anthropologie*, 1905, T. 16, No. 3, pp. 257–267.

RECENT CAVE EXPLORATIONS IN CALIFORNIA

Introduction

During the last three years a series of investigations has been carried on by the Department of Anthropology of the University of California, with a view to determining, if possible, the time when man first appeared in this region. As cavern deposits have furnished some of the most important materials in the study of early man in other regions, it was considered desirable, as one of the phases of this work, to make a careful paleontological and archeological investigation of the numerous limestone caves of the state. In this study the effort has been made to obtain as complete a knowledge as possible of the mammalian faunas which have existed in this region between early Quaternary time and the present. Man is considered as a possible element of the fauna, and so far as his geographic or his geologic occurrence is concerned he must be subjected to investigations of much the same character as are used in the study of other organisms. Until the facts of this class are determined, it is difficult to make a beginning on matters which are perhaps more definitely anthropological.

The discovery of human relics, apparently in association with remains belonging to a Quaternary fauna, in the extreme southern portion of South America leads one to suspect that an early migration of the human type may have passed over North America into South America. That other mammalian types came into America in fairly recent geological time we know, and there is no inherent improbability in the theory that man came with the other mammals. If his remains are found with a Quaternary fauna in the southern continent there is good reason why we should search for them here.

Up to the present time only a few caves situated in Calaveras county and in Shasta county have been examined. Many other

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Paper presented at the meeting of the American Anthropological Association, San Francisco, August 30, 1905. Including a partial report to the American Committee of the Archæological Institute of America on the explorations made under an appropriation by the committee for the work in 1905. *American Anthropologist,* ser. 2, vol. 8, no. 2, pp. 221–228, April–June 1906; *Congrès International des Américanistes, XV session* (Quebec, 1906), vol. 2, pp. 139–146, 1906.

occurrences are known, but limitations of time have made it impossible to visit these localities. One would hardly be justified in stating that as yet more than a beginning has been made on the possible cave investigations of California. It is to be hoped that in time these studies, in connection with the other phases of this work, may give us some definite information regarding the date of man's appearance in the Pacific Coast region.

Mercer's Cave

In the summer of 1901 Professor F. W. Putnam and the writer examined several caves in the vicinity of Murphys, Calaveras county, and in 1902 Dr. W. J. Sinclair visited a number of caverns in the same region. The most interesting remains encountered were those in the well-known Mercer's cave near Murphys. In this cavern there were found a number of bones of an extinct ground-sloth, which has recently been described by Dr. Sinclair as the type of a new species, *Megalonyx sierrensis*.[1] The bones of this animal were covered with a deposit of stalagmite, ranging from a few millimeters to about half an inch in thickness. From their situation it appeared that the body of the animal had fallen into the main chute of the cave, and in the process of decay the remains had been scattered for a considerable distance along the passageway. In the same cavern, although not in close proximity to the *Megalonyx* remains, there were found a number of human bones bearing a very thin calcareous incrustation. It appears that in this region it has been at some time the custom of the aborigines to throw the bodies of their dead into such caverns as this, and in places great numbers of skeletons have accumulated. The human bones found in this cave were in such position as to indicate that they had been thrown into the first chamber through the small opening above, while the *Megalonyx* remains had fallen some distance below this chamber. While it is exceedingly difficult to form any estimate of the relative ages of the human bones and the *Megalonyx* remains, such evidence as we have seems to indicate that the remains of man are the younger, as they are nearer the opening and are covered with a much thinner layer of stalagmitic material. The human bones are, however, probably many years old. While the relative thickness of the covering of stalagmite is in itself no absolute criterion as to the age of the enclosed material, as it may accumulate very rapidly in one place and very slowly in another place, it is probable that the thinner layer on the human bones means a shorter period of entombment.

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[1] Wm. J. Sinclair, New Mammalia from the Quaternary Caves of California, *Publ. Univ. Calif.*, Geology, vol. 4, no. 7, p. 155.

POTTER CREEK CAVE

The most extensive investigations of the caverns have been carried on in Shasta county. In this region two large caves have been very carefully explored and the principal deposits almost completely worked over. These are Potter Creek cave, on the McCloud river, near Baird, and the Samwel cave, on the same river, fifteen miles above Baird.

Potter Creek cave was the first to be the subject of careful investigation. It was discovered in 1878 by Mr. J. A. Richardson, and by him several specimens of fossil bones were sent to Professor E. D. Cope. In the summer of 1902 Mr. E. L. Furlong explored the cave again, without knowing that it was the one discovered by Mr. Richardson. Large deposits of fossil remains were found, and excavation work was carried on by him and by Dr. Sinclair through that season. Throughout the whole of the summer of 1903 the work was in charge of Dr. Sinclair, whose excellent report[2] on this work has already been published. The floor of the cave was carefully surveyed and all specimens taken out were labeled with reference to their position in the strata. The deposits were excavated to a depth of 25 feet, below which there seemed to be little but an accumulation of stalagmite-covered bowlders. The exploration work furnished several thousand bones and fragments, of which between 4,000 and 5,000 were determinable specimens. The remains include those of many extinct animals, and furnish the most satisfactory representation of the Quaternary fauna of California that has yet been obtained in any one locality. Fifty-two species were listed by Dr. Sinclair, of which at least twenty-one were found to be extinct.

Associated with the remains of the Quaternary fauna in Potter Creek cave there were many broken, splintered, and polished bones, which were carefully investigated by Dr. Sinclair, having been considered as possibly representing the work of man. The presence of the splintered bones is yet to be thoroughly satisfactorily explained, though there are many ways in which they might have been formed or introduced. In the caves of Europe such splintered bones are in part due to the splintering of long-bones of large mammals by man, and in part to the crushing of such bones by the larger carnivores.

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[2] *Publ. Univ. Calif.*, North Amer. Archæol. and Ethnol., vol. 2, no. 1.

The character of the pointed and polished bones figured by Dr. Sinclair in his paper is also difficult to determine with certainty. These polished fragments strongly resemble many of the roughest implements found in the deposits of the shell-mounds of the Pacific coast. Possibly they have been rough bone splinters, used by man until they attained the degree of polish which we find upon them. On the other hand it is noted that in nearly all shell-mound fragments the polish is mainly upon the pointed portion of the implement, while the portions not used for active work may be almost without smoothing or polish. In the specimens from the caves the polish is almost perfectly even over the whole surface in every case. The evenness of this polish seems to indicate that, if these objects were used as implements, special pains must have been taken to polish those portions which would in the course of ordinary use be left rough. Such smoothing as we see here may perhaps be as readily explained by the action of water as by any other means, the fragments being rubbed on all sides and evenly polished.

In other bone fragments, peculiar perforations and notches have been noted which are not easily explained by the operation of natural processes, but which could be accounted for by perforation through human agency. Of all the evidence which has been advanced in favor of the influence of man in the production of implement-like objects found in the Shasta caves, the evidence of perforation seems probably the strongest. A serious doubt must exist, however, as to whether the presence of only a few somewhat indefinite perforations in a very small number out of several thousand of these fragments should be considered proof of the presence of man. Had a large percentage of the fragments been formed and used by man, evidence of a more definite character ought to be present in abundance.

While it is probably true that as yet no unequivocal evidence of the agency of man in the fashioning of the bone fragments from this cave has been presented, in all fairness to those who may undertake from the study of such materials to give us something of the earliest history of the human race, we should not forget that, at the very period where the discrimination between artifacts and natural objects is most important it becomes most difficult. In the early stages of the development of man, such implements as were used by him were probably in many cases simply special forms of natural objects which were, in their original form, well adapted to meet his primitive needs. The earliest true artifacts were objects of this class showing only a little modification.

A more detailed discussion of the peculiarly marked bone fragments from the California caves is presented by Professor F. W. Putnam in a paper on this subject appearing also in this number of the *American Anthropologist.*

Samwel Cave

The exploration of the Samwel cave, in the Shasta region, has been carried on by Mr. E. L. Furlong through parts of the seasons 1903, 1904, and 1905.[3] This cave is somewhat larger than the one at Potter creek and contains several chambers of considerable size. The largest chamber had not been entered previous to 1903, when it was explored by Mr. Furlong and the writer.

Opening into one of the passageways about 100 feet from the entrance is a fissure containing a small alluvial fan, which opens out on the floor of the chamber. This deposit appears to have accumulated through the entrance of material from the upper part of the fissure. The entrance is now closed with a stalagmite growth, and no clue to its position has yet been obtained from the study of the surface of the rock outside. In small pockets on the sides of the fissure, and in the deposit below, there have been found large numbers of bone fragments representing a Quaternary fauna. These include remains of extinct species[4] of *Equus*, *Elephas*, and *Ursus;* also remains of *Euceratherium*,[5] a recently described sheep-like ungulate found in these caves, and bones of a ground-sloth somewhat similar to forms found in the caves of Brazil.[6]

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[3] The explorations during the season of 1905 were carried on under an appropriation from the Archæological Institute of America for the "Exploration of Caves in Northern California under the supervision of F. W. Putnam."

[4] See E. L. Furlong in *Science*, n. s., vol. 20, p. 53.

[5] Sinclair and Furlong, *Univ. Calif. Publ.*, Geology, vol. 3, no. 20.

[6] Sinclair, New Mammalia, op. cit., p. 153.

The largest chamber of the Samwel cave is at a lower level than the entrance and the fissure deposit. It was entered from above through a long chimney. In this chamber there was found a large deposit of fossil remains, including numerous extinct species. Among these were *Euceratherium*, *Preptoceras*[7] (another new sheep-like form), and a ground-sloth. It seemed improbable that the remains in this lower chamber had come in through the passage by which we first obtained entrance, and a careful search revealed the presence of an alluvial fan coming in from one side of the cavern. Excavations into this indicated that it reached out toward the surface, and during the last season a passageway was cut through it to an outer grotto on the side of a small cañon near by. The lower chamber was originally reached by a passageway leading from a large shelter cave now represented by the grotto. A part of the roof of the original shelter has broken down, and is represented by several large blocks which have fallen from the cliff above.

In the Samwel cave numerous splintered and polished bone fragments have been obtained, and the problems with relation to man are practically the same as those of Potter Creek cave. In addition to these objects, there was found in the chamber near the fissure deposit, a chipped fragment of basaltic lava, which appeared to have come from a point six inches below the surface of the stalagmite. Also in the excavation of the outer grotto of the largest chamber, a chipped obsidian fragment was brought up in the bucket from a depth of eleven feet, at which level bones resembling those of an extinct species have been obtained. In neither case, however, was the chipped fragment actually seen in place, and both must be set aside, for the present, as merely suggesting the presence of man.

STONE MAN CAVE

A third cavern in the Shasta region, which has been partly explored, is the Stone Man cave about one mile northeast of Baird. It was visited by Mr. Furlong and the writer in 1903. In one of the uppermost chambers a number of bone fragments were found in the stalagmite. These were, however, too imperfect for specific determination, and the age of the deposit has not been determined. In one of the lower galleries, a portion of a human skeleton was found imbedded in the stalagmite. The greater number of the bones had been removed before our visit, but enough was left to show that a considerable fraction of an inch of stalagmite has accumulated on the skeleton. Mr. J. A. Richardson kindly gave us a vertebra which he obtained here when the cave was first explored. It seems to have lost practically all of the organic matter, and the cavities in the bone are largely filled with calcite crystals. In this cave there is unfortunately nothing to fix the age of the skeleton definitely. It might easily be many centuries old, or might have come to its present location at a comparatively recent date, though evidence rather favors a considerable antiquity.

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[7] E. L. Furlong, *Univ. Calif. Publ.*, Geology, vol. 4, no. 8.

Age of the Cave Deposits

The faunas of both the Potter Creek and the Samwel cave indicate Quaternary age. As far as is now known, the fauna of Samwel cave contains the larger percentage of recent species and is probably the younger. In addition to this evidence, the situation of the two caverns gives considerable information regarding their relative ages. Potter Creek cave is situated at a height of 800 feet above the level of McCloud river, and just below an ancient terrace level of the river. The Samwel cave is situated just below a terrace 350 feet above the McCloud. The lowest chamber of this cave opens at a point not more than 200 feet above the river. Both caverns were evidently formed at a time when McCloud river was near the level of the terraces above them. Both received their principal deposits when the river was a short distance below them, and it is evident that the time which has elapsed since the formation of the deposits in Potter Creek cave is much greater than that since the formation of similar beds in the Samwel cave. The evidence of physiography apparently corroborates that obtained from the study of the fauna.

The fauna of Potter Creek cave is considered by Dr. Sinclair to represent the middle or later Quaternary. The fauna of Samwel cave is certainly Quaternary, but is evidently later than that of Potter Creek. The age of Potter Creek cave is, according to commonly accepted correlations, not far from that of the earliest deposits containing human remains in Europe. Though a reasonable doubt might arise as to whether man could have reached America as early as the date of the Potter Creek deposits, the age of Samwel cave appears to be within the period of man's existence in the old world.

From the evidence at hand it seems that both Mercer's cave and Stone Man cave were in existence in Quaternary time, and in all probability some of the deposits in both caverns were formed in that period.

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NOTE ON THE OCCURRENCE OF HUMAN REMAINS IN CALIFORNIAN CAVES

In the course of an investigation of some of the limestone caverns in California during the last four years, a number of cases have been noted in which human remains were found in such situations as to indicate that their entombment was not of historically recent date. In no instance have any specimens been discovered which can be said to be of Quaternary age, although some of the occurrences are of such nature that it would be difficult to prove that the remains were buried during the present period.

The writer has already called attention[1] to the occurrence of human remains in Mercer's Cave in Calaveras County, and in the Stone Man Cave in Shasta County, under conditions which certainly suggest a considerable antiquity. In Mercer's Cave a number of human skeletal remains were found in close proximity to the bones of a Quaternary ground-sloth. The bones of both sloth and man were incrusted with a deposit of stalagmite, the incrustation on the sloth bones being considerably thicker than that on the human remains; and it is not probable that they were buried at the same time. It is, however, true that stalagmite deposits may be very uneven, and it is possible that the covering on the ground-sloth was formed in a shorter time than the thinner layer on the human bones.

The remains in Stone Man Cave were discovered in a remote gallery of this extensive cavern. The greater number of the bones were embedded in a layer of stalagmite which enveloped them to the thickness of one eighth of an inch or more. A vertebra which was obtained many years ago from this locality is found to have lost most of the organic material, and the cavities are largely filled with calcite crystals.

In neither of the cases just described is it possible to fix the age

Science, n. s., vol. 30, no. 772, pp. 531–532, October 15, 1909.

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[1] "Recent Cave Exploration in California," *American Anthropologist*, N. S., Vol. 8, No. 2, p. 221.

of the remains, but the impression given in both instances is that some centuries have elapsed since the skeletons came into the position in which they were found.

Another interesting occurrence of human bones has recently been brought to the notice of the writer by Dr. J. C. Hawver, of Auburn, California. During the past few years Dr. Hawver has engaged in an energetic exploration of the limestone caves in the vicinity of Auburn, partially at the instance of the University of California, but largely on his own resources. Hawver Cave, discovered by him and recently named in his honor, has been explored and described by Mr. E. L. Furlong,[2] but Dr. Hawver has continued the exploration of this cavern farther than it was carried by the university. In March, 1908, while attempting to open what Dr. Hawver supposed to be an ancient passageway into the lower cave, a number of human bones were found at a depth of twenty feet below the surface, under a mass of cave earth, fallen rocks and soil, over twelve feet in thickness. The remains lay at the lower end of a passageway which has evidently been closed for a long period. In this case, as in that of Mercer's Cave, remains of extinct animals undoubtedly of Quaternary age were found near the human bones, but the degree of alteration of the unquestionably Quaternary bones differs from that in the human skeletons. Some of the human bones were embedded in a cemented breccia consisting largely of angular fragments of limestone. So far as examined the bones seem to have lost most of their organic matter. A fairly preserved skull in the collection does not differ strikingly from the crania of the modern California Indians, although no comparative study has yet been made by a specially trained craniologist.

It is not possible in the case of the Hawver Cave relics to prove Quaternary age for the human bones. As in the other instances mentioned, the inference is, however, that the date of their entombment preceded the present day by centuries, if not by millenniums.

University of California

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[2] Furlong, E. L., Science, N. S., Vol. 25, p. 392.

THE RELATION OF PALEONTOLOGY TO THE HISTORY OF MAN, WITH PARTICULAR REFERENCE TO THE AMERICAN PROBLEM

Considered in its broadest aspect, the most important relation of paleontology to the study of man concerns the support which it gives to the general theory of evolution of the organic world. If it be held that we have reason to believe man, with all his highest qualities, a product of evolution out of so-called lower animal types, then it becomes necessary to have a full knowledge of the history of man and of the forms preceding him, in order to understand the origin and the true nature of man's fundamental characteristics as they exist today. On the other hand, if there is reason to believe that man as represented in his highest attributes is entirely apart from nature, the importance of paleontology, as offering a part of the explanation of the fundamental characteristics of man, is very greatly diminished. The value of paleontology would in that case lie largely in an interpretation of the setting or environment in which man is developing.

With these considerations in mind, it appears of the greatest importance for us to obtain as full a history of the organic world, and as satisfactory an interpretation of the processes therein concerned, as it is possible to secure. Particularly is it desirable to have before us a clear statement of that portion of the paleontological record which leads from the higher vertebrates through the primate division to man.

One of the important phases of general paleontological work which must receive special attention is the early history of the primate order with particular reference to the development of those characteristics which are most prominent in the human family. We have, as yet, accumulated too little evidence in this field. Among the characters which must be followed would be (1) extraordinary brain development, (2) the tendency to development of an upright position, (3) the freeing of the anterior limbs from the work of

Popular Science Monthly, vol. 77, pp. 597–601, December 1910.

locomotion and the development in them of extraordinary adaptability. Whatever other interests one may have, there is certainly no more alluring problem than tracing from the primitive mammalia into the early primate those peculiar characters through which later on primitive man began the process of making nature subservient to himself. We may never know whether the brain actually grew large first and requisitioned the hands, so that the animal became bipedal and therefore finally erect in position, or whether a tendency to erect position was directed by the frequent assuming of a vertical position in a tree-climbing ancestor; but it is not beyond reason to presume that a thoroughly satisfactory paleontological record might give us an explanation of the origin of these characters.

The later primate history, or that which leads directly to the human type, is also unfortunately incomplete, though most remarkable advances have been made in the last few years. More missing links have already been furnished than science was supposed to require a few decades ago, but we can hardly be said to have one tenth of the material that it is desirable to have in order to show the transition from anthropoid to human, or from pithecanthropoid to the type of Spy or Neanderthal. European paleontologists are at the present time making rapid strides in filling the gaps of that portion of our ancestral chain which falls in the Quaternary system, and we may look for other important discoveries within the next decade.

It is to be presumed that the greater part of the work on the late Tertiary and Quaternary history of man will be carried on in the old world. The writer sees no reason why in this important work American paleontologists should not interest themselves to some extent in investigations now in progress in Europe and Asia, just as American archeologists have contributed to the success of work on the later history of man. Whether American paleontologists, working in their own field, are to have a part in interpreting the Pleistocene history of man is a burning question at the present time.

Whether we find that man was in North America in Pleistocene time or not, it is certainly true that one of the most important problems in the general history of the human race concerns the date of occupation of the western hemisphere by the human family. The numerous finds reported to represent Pleistocene man in North America are too well known by every one to require particular mention. It should only be noted in passing, that as yet no specimens representing either skeletal remains or implements of man found in North America are generally recognized by geologists and paleontologists as of Pleistocene age. A careful search through the literature, and the investigation of many of the actual occurrences, lead the writer to the conclusion that we have, as yet, nothing in North America which can be considered as unquestionably representing Pleistocene man.

Also in South America there has been serious discussion of many interesting finds. The evidence on the whole seems to be more distinctly in favor of Pleistocene occupation there than is the case in North America. The discoveries made in recent years in the cave at Last Hope Inlet, and the numerous remains found in the Pampean formation at levels very far below the surface, seem difficult to interpret excepting on the supposition that man was present in South America before the beginning of the recent epoch.

It is to be presumed that any occupation of South America would necessarily be through migration by way of the northern continent, and proof of the presence of man in South America in Pleistocene time would be tantamount to proof that he was in North America at least as early. This suggestion does not, of course, take into account the theories of Ameghino to the effect that man is possibly derived from some of the South American monkey forms. Another suggestion made by Ameghino would give us an immigration of old world forms, possibly with ancestral man, coming into the southern continent in comparatively late time, by some other route than North America.

In the consideration of man's history in America, it is particularly important to notice the probable relation of migrations of the human family to migrations of other groups of mammals. The presumption is that the migrations of primitive man were caused or occasioned largely by influences of the same sort as have produced the spreading out or migration of many other mammalian types. It becomes then particularly necessary to discover exactly when the more recent migrations of mammals into the North American continent have taken place, and, so far as possible, the exact routes of migration. This problem is in a large part paleontological, requiring for its interpretation a satisfactory account of the paleontology of vertebrates, invertebrates and plants of North America and of Asia, with particular reference to the relations of adjacent areas.

We must also have, associated with this information, a full statement of the crustal movements in these regions as interpreted by the stratigraphic geologists and the physiographers.

Through the accumulated efforts of paleontologists in this country particularly, we have already a considerable mass of evidence bearing on the general relationships of the faunas of North America and Asia in comparatively recent geological time, but the detail of the problem is, as yet, scarcely indicated. Particularly for Pleistocene and Pliocene time our knowledge of the faunal succession is exceedingly meager, and we can scarcely expect to know anything satisfactorily until the Pleistocene mammalian paleontology of America has been worked out in detail. This work must be followed or accompanied by similar studies of the mammalian faunas of western and southern Asia. When this is completed we shall know the time of the various migratory movements, the nature of the faunas which migrated, the character of the land areas over which they have passed, and the climatic conditions which obtained along the routes of migration. The presumption is, that when this is done we shall have actual evidence of the time of man's occupation of North America.

Viewed in the large, and without regard to the detail which has just been indicated, it seems possible to present several reasonable conclusions with reference to the probable period of migration of man to America. It is shown by study of a map of linguistic stocks of the western hemisphere that the northern and southern continents taken together may be divided into between one hundred and two hundred provinces, based on the number of stocks represented. These languages vary greatly in their structure, and are not similar to the languages of other parts of the world. There is every reason to believe that a large percentage of them have been developed by linguistic differentiation which occurred since man first occupied this continent, and that measured in years the time required for this differentiation has been long. On the other hand, considering the American continent as a whole, we find that the greatly differing physical environments are not reflected to any extent in different physical types of people occupying this region. That the human family is not exempt from physical differentiation, such as is almost universally indicated in mammals which have for some time been distributed over large areas with varying environments, is clearly shown by the map of the old world. In that region the human race is known to have been spread over a wide area for a long period, and we find several greatly differing human physical stocks in different geographic regions, just as we find differing stocks of mammals and birds.

With the lack of physical diversity among the people of the western hemisphere, there is also noticeable a resemblance of the whole group to the people of the adjacent region of Asia. Judged by the standards of differentiation which we obtain through a study of the history of geographical distribution of other mammalian groups, we have every reason to think that the people of America are immigrants who came from the Asiatic region and spread themselves over America after the period of the first great physical differentiation of the race, and so recently that a second stage of physical differentiation has not yet had time to develop. On the other hand, the time measured in years has been long enough so that linguistic differentiation could take place.

Inasmuch as a large part of human history falls within the Quaternary period, the question naturally arises as to whether the principal migrations of man to the American continent occurred *before*, *during* or *after* the Glacial epoch.

As all primates are naturally animals of a warm or temperate zone, it is hardly to be presumed that primitive man came to America *during* the ice age, though there is a possibility of immigration in some of the interglacial epochs. Judging from what is learned through study of physical differentiation, it appears improbable that man came over as early as the epoch preceding the ice age. In other groups of animals spread over large areas, marked physical differentiation has ordinarily taken place in a space of time comparable to the Glacial epoch. Had man been present in America during this long period, widely differing physical types would almost certainly have developed. On the whole it seems most probable that he arrived after the end of the last division of glacial time, or very near the beginning of the present epoch. Whether his arrival is shown to have occurred just before or just after the beginning of this epoch remains to be determined.

In conclusion it seems desirable to call the attention of paleontologists once more to the important part which their work must play in obtaining the information which we need with reference to the history of man and his antecedents. Only a small beginning has been made, and the results which must come are of great importance in the large problem of man's relation to nature. It is necessary that paleontologists keep the subject before them, in order to make certain that all information bearing upon it may be recognized as it becomes available, and be given its proper place in relation to other evidence now at hand.

THE FOSSIL HUMAN REMAINS OF TABLE MOUNTAIN

The exceedingly interesting discoveries of human remains and relics made in the later geological formations of California have unfortunately never received from scientists or the public the attention which they really deserve. Bret Harte's humorous poem[1] and the religious press destroyed the general interest in the Calaveras skull, while the seemingly impossible character of that which is claimed for the Pliocene or Quaternary man of California, has restrained the scientific world from receiving much of the evidence brought forward to prove his existence.

Some of the most interesting of these ancient human remains from California, are those discovered in and near Turlumne Table Mountain, in the foot-hills of the Sierra Nevadas. The Table Mountain is really a chain of flat-topped hills and ridges, originally connected, extending northeast from Knights Ferry for many miles, along the course of the Stanislays River. Aside from the interest which attaches to it on account of its being a celebrated locality for fossil human remains, the Table Mountain is a remarkable piece of geological structure and has been a noted gold producing region.

A section through any of the ridges shows the top to be a stratum of hard, black lava about 150 feet thick, which is underlaid by sandstone, clays, gravels and slates, the latter being the country rock, on which the mountain stands. It has been noticed, moreover, that while the strata of lava, sandstone, clay, etc., are in a nearly horizontal position, the slates stand on edge and form an irregular surface, on which the younger strata rests. The miners noticed long ago that a drift run into the mountain might start in the slates, and after passing some distance, strike the softer horizontal strata resting in a basin or channel-like depression of the country rock; the slates were therefore named in this connection "rim rock," while the channels with their contained gravel beds were recognized as old river courses.

Lenox Nutshell (Hopkinton, Iowa), 1898.

[1] To the Pliocene Skull (a geological address).

The whole structure of the Table Mountain indicates that it is built upon the bed of an ancient river. When the channel was first cut to its present depth the "rim rock" probably rose as high hills on either side of the stream, then beds of gravel, sand, and clay were deposited in the river bed to a thickness of many feet and finally, a great lava flow, coming down from the Sierras through the easiest channels, filled the valley nearly to the brim. As the lava is much harder than the slate, it was natural that when the river again deepened its channel it should leave the lava bed and cut into the slates. Since the period of the lava flow, extensive erosion has take place in that region and the river has cut down about 2,000 feet, while the Table Mountain sediments, protected by the hard lava cap, are left standing to serve as sepulchres for the bones of prehistoric man.

In the clay and sand, which form the greater part of the river deposits beneath the lavas, there are found remains of numerous fossil plants and animals, all, or nearly all, of which belong to extinct species, and in the gravels forming the bottom of the series, human bones, with implements and utensils, evidently the product of human workmanship, have been discovered. The plant remains, which are beautifully preserved in a white volcanic ash or mud, are all said to belong to species no longer existing in California. The bones and teeth of animals found, are those of the mastodon, horse, and possibly of the hippopotamus. In other similar deposits, probably of the same age, occurring near Table Mountain, there have been found, in addition to these remains the bones of the mammoth, rhinoceros and a kind of camel.

The human remains taken from the excavations beneath the lava, consists of a jaw and portions of a skull. Among the relics discovered, were stone mortars and pestles, spears or ax heads and a stone bead. The authenticity of these finds, particularly those of the human bones, has been questioned and the commonly accepted theory of their origin is that most of the accounts of such discoveries are absolutely false, intended only as jokes, and that where remains were actually found in mines they had gotten in accidentally or had been carried in by workmen. Against these doubts it must be urged that many of the numerous discoveries were made by men of good character, who have not been given to practical joking or deception while one of the relics, a pestle, was taken from the gravels below the lava, by the noted geologist, Clarence King. The finds were moreover made at several different localities and were scattered through a series of fifteen or twenty years.

When compared with the remains of prehistoric man known from other parts of the world, the Table Mountain specimens seem to differ from all others in the relation of the stage of their development to their age. The age of the specimens is measured by the time it has taken to deposit the beds of sandstone and clay above the horizon at which they are found, plus the time taken by the river to cut down from its position on the top of this series of strata to its present level. Judging by what is known of the rate of deposition and channel cutting elsewhere, the amount of time required for the work done by river action at Table Mountain, since the deposition of the strata containing human remains, is as great or greater than that which has elapsed since the entombment of the oldest human remains known from other parts of the world.

On the basis of what is known of the stage of culture of the oldest human beings, as indicated by the character of their implements and utensils, the stone age or first age of human history is divided into two periods, the older or Palaeolithic and the newer or Neolithic. The stone relics of the Palaeolithic period are rough and rude, evidently the work of men as yet possessed of little skill in any art. The skulls of the men of this period show receding foreheads and have a small brain capacity. Among the bones of animals found associated with the remains of Palaeolithic man, are those of numerous species now extinct, as the mammoth, rhinoceros, cave bear, cave hyena, etc., but no bones belonging to our modern species of domestic animals are found in these deposits.

The Neolithic remains are of a much higher type than those of the preceding period, the implements are sometimes highly finished, and the human skulls have a greater brain capacity, indicating a higher degree of intelligence. Bones belonging to some of our modern species are not rare among the mammalian remains associated with those of Neolithic man, while the mammoth and rhinocerous seem to be absent, showing that man had already begun his subjugation of the beasts. When we compare the Table Mountain implements and bones with those belonging to the stone age of Europe and elsewhere they are found to agree in their stage of development much more closely with the Neolithic than with the older or Palaeolithic remains. In fact the Table Mountain relics differ little from those that might have been found in many Indian camps in California a few hundred years ago.

From a purely scientific standpoint, the presence of these modern or Neolithic types of implements in strata apparently of great age, which contain moreover numerous remains of extinct animals and plants, is not easily understood and has so far received no adequate explanation. At the present time the scientific world hesistates as to whether or not it should accept the statements made regarding the occurrences of fossil man in California, though some, and among them a number of the most noted geologists of this country, harbour no doubts as to the accuracy of the observations which have been made. The hesitancy shown by scientists, it might perhaps be stated, is due to a greater extent to the exceptional character of the occurrences than to skepticism as to the evidence produced to prove the authenticity of the discoveries. No matter how the questions as to the origin and history of these apparently very ancient human remains from California may be answered it is probable that the results of future investigations in this field of research will have important bearings on the history, and perhaps on problems relating to the origin of the human race.

PRELIMINARY REPORT ON THE DISCOVERY OF HUMAN REMAINS IN AN ASPHALT DEPOSIT AT RANCHO LA BREA

Introduction

In January, 1914, the Museum of History, Science and Art of Los Angeles, being inconvenienced by heavy rains filling the pits already in process of excavation in the asphalt deposits at Rancho La Brea, began work at a new locality, which was designated as pit number ten. Work was started at a point a short distance southwest of a large pit from which many remains of extinct animals had been obtained in previous years. The point at which excavation was initiated was marked by a seepage from which tar had poured out in comparatively recent time. The excavation of this locality showed the presence of two vents or chimneys filled with asphalt. The chimneys were each about three feet in diameter and both had contributed to a hard asphaltic layer forming the surface of the ground at this point. At a depth of about eight feet the chimneys opened into a large dome-shaped asphaltic mass not less than eight feet in diameter and extending downward to an unknown depth.

Remains of many kinds of animals were obtained in both chimneys, but the most interesting discovery was the finding on February 5 of an upper jaw from a human skull, at a depth of a little more than six feet, in the northerly of the two chimneys. Careful investigation of this vent disclosed later almost the entire skull with other portions of the skeleton. The remains evidently belonged to one individual. The bones were found ranging in depth down to a level of about nine feet below the surface, and reaching almost to the point at which the chimney connected with the dome-like reservoir below.

Realizing that this find might prove of exceptional scientific interest, unusual precautions were taken in the excavations fol-

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Paper presented at the Museum of History, Science and Art, Los Angeles, June 11, 1914.
Science, n. s., vol. 40, no. 1023, pp. 198–203, August 7, 1914.

lowing the discovery of the human remains. Under the direction of Mr. Frank S. Daggett, director of the Museum, and of Mr. L. E. Wyman, who had immediate charge of the work in the pits, the excavators obtained all possible information as to the nature of the deposit in which the specimen was found, and every bone appearing in the deposit was saved. The final results of the work give us a complete map of the deposit, and full list of the animal remains from the two chimneys, with their situation in the chimneys.

Through the courtesy of Mr. Frank S. Daggett, director of the Museum of History, Science and Art, it has been the writer's privilege to follow closely the course of the excavations in the pit in which the human remains were found, and to make a study of this most interesting occurrence. Most efficient assistance has been given in every possible way by Mr. Daggett, by Mr. Wyman, and by every one connected with the work. The handling of the excavation by the museum staff, and the careful exercise of precautions necessary to insure the scientific accuracy of the work, are worthy of most favorable comment.

Character of the Problem

As a part of the general problem of the history of the human family, involving questions of the origin and of the true nature of man, the history of the human race in America has interested every thoughtful person. The occurrence of human remains at Rancho La Brea, appearing as it has in close relation to a marvelous representation of life from a past period, has justly demanded attention.

The interest in the human skeleton from Rancho La Brea centers either on peculiarities in the character of the skeleton itself, or in evidences of its antiquity furnished by definite indications of the geologic age of the deposits in which it was found or through proof of age presented by the animals associated with the skeleton.

Nature and Origin of the Deposits Containing Human Remains

Purely geologic evidences of age are often exceedingly difficult to obtain in asphalt deposits, owing to the peculiar mode of accumulation, and the possibility of movement in the deposits after they are once formed. The asphalt is a residue from evaporation of oil. It accumulates either on the surface of the ground or in the midst of other strata into which it has soaked or poured. Even after the asphalt deposit has formed, the nature of the viscous material makes possible considerable movement in many directions within the mass, and consequent change of position of any materials in it.

The deposits in which fossil remains have been found at Rancho La Brea are evidently in part layers formed on the surface, and in part pipes, pockets and chimneys through which oil came up from deeply buried strata. The source of the asphalt or oil is a deep-lying formation, which is considerably folded, and is covered by approximately horizontal layers of clayey and sandy strata washed in from higher land not far away. Oil and gas have been seeping through the superficial horizontal deposit for a very long period, and have formed more or less definite channels or pipes along lines of least resistance. In some cases these pipes have evidently enlarged themselves locally to chimneys several feet in diameter.

At pit number ten, in which the human remains were discovered, the asphalt deposit consists of two pipes or chimneys connecting with surface flows above. The chimneys arise below from a large dome-shaped asphaltic reservoir. This dome may be an old surface pool now buried and forming a part of the passageway for further upward movement of oil; or it may be an enlargement of a chimney that was originally very much smaller.

The asphalt in the chimneys and in the dome in pit ten was largely a soft, viscous mass containing a high percentage of sand, and including in some regions many angular lumps of hard, weathered asphalt. The contents of the chimneys are entirely unlike the surrounding soil or rock. The material through which the chimneys pass is not homogeneous, but is composed of approximately horizontal strata of clay, sand and gravel, with a small inclusion of asphaltic material in most places. The contact between the chimneys and the matrix through which they pass was everywhere sharply marked.

The sand content of the asphalt in the chimneys and in the reservoir below is quite uniform in grain and in distribution through the mass. The sand may have been mingled with the tar by entrance through the upper end of the chimneys or may have been carried up from below. The available evidence favors the view that it came from the sandy layers from which the oil is seeping upward, or through which the oil passes on the way.

The lumps of hard asphalt embedded in the soft sandy matrix in one chimney are generally of irregular form, and may be much oxidized or weathered. They were evidently derived from asphalt masses that were oxidized by exposure to the weather for a considerable time. They are not found in the dome below and evidently came into the chimney from above.

The chimneys in pit ten may have originated through gradual building up of the walls around open pipes connected with the oil-supply below. They may have developed as channels forced through deposits already formed. Regardless of the mode of origin, the chimneys have certainly been passage-ways through which asphaltic materials have moved sometimes up and sometimes down for a period of unknown extent. It is not improbable that at one time these pipes were longer than at present, the surface of the ground being at a relatively higher level. Erosion may have carried away many feet of deposits at this point, shortening the chimneys much below their length at an earlier time. If the history of these chimneys is like that of some now open in this region, they may have spilled their contents widely at times, and on other occasions, the tar may have receded, so as to leave long empty tubes or chambers. If such a period of recession lasted any great length of time, one would expect the tar around the opening above and adhering to the walls of the tube to be much weathered.

In various ways, dry, oxidized pieces might be broken off around the vent and accumulate as angular fragments below. A later rising of the tar would give a mixture of tar, sand and weathered lumps. If the whole chimney stagnated and oxidized for a time, a later outbreak of oil or asphalt following along the side of the old channel would give two parallel pipes filled with somewhat different materials.

As nearly as one can judge from observations available, the north chimney had a varied history presenting stages like most of those discussed as possibilities. The south chimney, containing only soft, sandy asphalt, evidently had a more uniform history or a shorter history.

REMAINS OF ANIMALS FOUND IN THE PIT CONTAINING HUMAN REMAINS

Bones of birds and mammals were abundant in both chimneys. In the south chimney, which is wide above and narrows sharply below, large bones are found only above the narrowing of the pipe. In the large reservoir below the chimneys only small bones appear, and these were found only in a limited space near the point of union of the lower reservoir and the two chimneys. The distribution of bones shows conclusively that they came from above, and were not carried up from the depths with ascending oil.

The total number of specimens found in the chimneys was large, and will aggregate several thousand. These bones represent a considerable variety of mammals and birds. They include bear, coyote, a wolf of the timber-wolf type, skunk, weasel, horse, antelope, rabbit, pocket-gophers, field-mice, eagles, owls, vultures, crows, and many other forms.

The fauna from the two chimneys in pit ten is in general like that of California at the present time. It differs greatly from that of the pits in which the well-known Rancho La Brea fauna is found through the absence of the great wolf, saber-tooth, sloth, small antelope, camel, and many other mammals and birds abundantly represented in the typical Rancho La Brea deposits.

The only extinct form certainly recognized in the material from the two chimneys is *Teratornis*, a gigantic condor-like bird, as yet known only from Rancho La Brea, and recognized by Dr. L. H. Miller in this collection. Bones of this bird were found in a narrow portion of the north chimney at a depth of about four feet, and considerably above some of the human remains. As nearly as one can judge from the evidence at hand, there seems a reasonable chance that the giant *Teratornis* was a contemporary of the human being whose remains appear in the north chimney of pit ten. The evidence does not present clear proof in favor of this view, but appears to balance in that direction.

The extinct California peacock and two other extinct species are doubtfully reported from the north chimney, but there is doubt as to their having been introduced in the same manner as the other bones making up the fauna.

A small collection found near the upper end of the north chimney contains a number of birds, which, according to Dr. Miller, are quite different from those certainly known from the two chimneys. The matrix in which this small collection was found is also different from that in the chimneys. It seems probable that these specimens really represent an older fauna embedded in a relatively ancient deposit through or near which the north chimney passed.

A portion of the lower jaw of a young horse found at a depth of about five feet and near the *Teratornis* in the north chimney is more slender than any lower jaw of the common extinct horse found in the typical Rancho La Brea fauna. The writer has not, however, compared it with fossil specimens of exactly the same individual stage of development. In slenderness it approaches more closely the jaw of the existing domestic horse. The space between the back teeth and front teeth seems shorter than that in the domestic horse, and is of nearly the same length as in the extinct species from Rancho La Brea. A more careful study of immature specimens from Rancho La Brea in comparison with very young modern horses will be necessary before one can speak authoritatively with reference to the specific determination of this specimen. It will be very interesting to know whether this is an extinct species which lived in California until a comparatively recent time and was contemporaneous with man, but became extinct before this country was visited by white men. The alternative hypothesis is that it represents the colt of a modern horse which fell into the pit within the last century and a half.

The fact that the fauna from the two chimneys is nearly or quite identical with that of the present day, while the typical Rancho La Brea fauna differs greatly and shows close resemblance to the life of the earth at a remote time, makes it evident that the fauna represented in the chimneys of pit ten pertains to a period much later than that in which the typical Rancho La Brea animals lived. The collection from the chimneys represents a time so close to the present that the types of life were nearly the same as those in the region at the present day. The giant *Teratornis*, and possibly several other extinct forms in this fauna, may indicate that the asphalt in these chimneys was trapping animals at a time removed by some thousands of years from the present. On the other hand, it may be that these species were living here within historic time. A third possibility is that the bones of such extinct species as are found here have been removed in some way from an older deposit, and found a resting place in the chimneys in comparatively recent time. Still more remote is a fourth possibility that in Pleistocene time these chimneys connected with an open pool far above the present surface of the ground; that bones of a few animals trapped at that time sank to the position in which they were found in the excavations; and that after the removal of the upper deposits by erosion, the later or younger fauna was trapped and mingled with the few bones of earlier date.

The Human Remains

The human bones were all found in the north chimney, where the history of accumulation is more complicated than in the south vent. The pit containing the human remains also contains all of the presumably associated specimens representing extinct animals.

The human remains were found rather widely scattered between a depth of about six feet and nine feet. The whole collection of human bones seems to represent one individual. The bones are generally very much worn. The wear in some cases suggests movement within the pit in such a manner that sand in the tar, or resting against the wall of the chimney, has cut away the bone by long-continued rubbing.

Enough of the human skeleton was found in the pit to give a fairly satisfactory idea as to the characteristics of the individual it represents. The skull is that of a small person of middle age, possibly a woman. The brain case is relatively as large as that in some of the living native races of America. According to Dr. A. L. Kroeber the racial characteristics do not differ decidedly from those of people whose remains have been excavated in mounds on Santa Rosa Island off the coast of southern California. So far as the characteristics of the skeleton are concerned, it is not necessary to suppose that we have here an individual who lived at a remote time when the human family was in a relatively low stage of evolution. This skull is not comparable to those of ancient races of the Neanderthal or earlier types. On the other hand, one must not forget that people of a fairly advanced stage of brain development were already in existence at the beginning of the present or Recent geological period.

The characters of the human remains taken by themselves indicate that this person lived either within the present or Recent period, or at a time not earlier than the end of the Pleistocene period immediately preceding it.

Conclusions

A summary of available information regarding the age of the human skeleton found in pit ten at Rancho La Brea is as follows:

1. The evidence of geologic occurrence in the asphalt chimney taken by itself counts for relatively little owing to the peculiar conditions under which these deposits are formed. In so far as this is of value it suggests an age later than that of the tar pits containing the typical Rancho La Brea fauna.
2. The fauna associated with the human remains in pit ten is quite different from the typical Pleistocene Rancho La Brea fauna, and must have inhabited this region at a different period. The fauna in pit ten is closely related to that of the present or Recent period. It is distinctly later in age than the typical Rancho La Brea fauna.
3. The characters of the human remains, taken by themselves, show a stage of development similar to that of man of the present day and not earlier than man of the latest Pleistocene time.
4. The evidence as a whole indicates that the human skeleton from pit ten is of a period much later than that of the typical Rancho La Brea fauna, the time being either within the Recent period or not earlier than the very latest portion of Pleistocene time. The possible association of the human remains with extinct forms, such as the giant *Teratornis*, may indicate some antiquity for the human being, or may indicate comparatively late persistence of birds or mammals now extinct in this region.
5. Measured in terms of years, it is not possible to give a definite estimate of the age of the skeleton from pit ten. It may suffice to state that this person did not live in the period of the low-browed, Neanderthal, Pleistocene man of Europe. It belongs to the distinctly modern stage of evolution. It does not necessarily belong to the present historic period, but can not be considered as having antedated it by many thousands of years. The age of this specimen may perhaps be measured in thousands of years, but probably not in tens of thousands.

6. The study of the remains at pit ten is a problem similar to that presented by the occurrence of an arrowhead found in a comparatively recent asphalt deposit encountered in the University of California excavations of 1912. The arrowhead was found embedded in a deposit somewhat similar to that in pit ten, and the fauna associated with it was in general of Recent aspect.

7. The final summing up of all evidence relative to the antiquity of the Rancho La Brea skeleton will depend on a very detailed and exhaustive study of the typical Pleistocene Rancho La Brea fauna, of the fauna from the later tar deposits like that of pit ten, and of the existing fauna of California. No one of these three factors is, as yet, satisfactorily known. Until they are all known, the last word on this subject can not be written. The significance of this statement may seem larger when reinforced by the remark that the skeletons of a large percentage of our living species have never yet been carefully studied in the way in which this work must be done for use in investigations such as those concerned in this problem.

From whatever point of view this specimen is considered, it is well worth exhaustive scientific investigation.

University of California
June 11, 1914

ANTIQUITY OF MAN IN CALIFORNIA FROM THE POINT OF VIEW OF THE PALEONTOLOGIST

Antiquity of Man in California from the Point of View of the Paleontologist: JOHN C. MERRIAM.

In working over the collections of the state geological survey of California in 1894, the writer's attention was particularly attracted by a collection of mortars and other objects of human manufacture, which, according to the accompanying labels, had been found in the Pleistocene gold-bearing gravels of California. Accompanying these collections were other objects of a similar nature reported by reputable observers to have been obtained in formations not younger than Pleistocene. Although the objects in question were not unlike implements manufactured by the Indians of California within very recent time, the evidence favoring their antiquity appeared so remarkably definite that it seemed worth while attempting to secure all the facts bearing on the question of the occurrence and age in order to obtain some explanation of the evident inconsistency. Numerous inquiries among intelligent observers of good repute regarding the occurrences of human remains and relics in the auriferous gravels of California brought out a considerable amount of information as to the finds already known, and added several important occurrences to the list available. At this time there were known to the writer not less than eleven cases in which, from the point of view of the unprejudiced observer, there seemed no question but that artificially fashioned objects had been found to be original constitutents of Pleistocene or earlier formation of the California region.

The plan of work thus outlined was beginning to furnish small results when the organization of the department of anthropology at the University of California, through the generosity of Mrs. Phoebe A. Hearst, made it possible to carry out the whole scheme

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of investigation, only a small portion of which it had seemed possible for the writer to undertake individually up to that time.

While it is evident that the human race did not originate in America, its occupation of the western hemisphere has apparently covered a long period measured in years, if it does not actually extend back to an earlier geological period. At any rate, the advent of man far antedated the beginning of the American historic period and the approximate determination of the date of his arrival, whenever it may have occurred, furnishes an important field for investigation in American history.

As a field for investigation of geologically ancient types of the human race, North America has been notably barren. Even those who have been convinced that man was present on this continent before the beginning of the present geological period must concede that the evidences of his existence are much less common here than in most parts of the Old World.

Of the several widely known discoveries of human remains and relics reputed to represent a geologically ancient type of man on this continent, some of the occurrences reported from California have most persistently forced themselves on the attention of the investigator, thought not always receiving general recognition as of scientific value.

It has been realized at the outset that any satisfactory conclusions in a work of this character are not to be arrived at within narrow time limits, and that no single mode of attack may be considered sufficient in itself. At the outset four lines of investigation were laid down: (1) Tracing man back from the known type to the unknown, through an investigation of the great shell mounds of the coast region, the most critical study being given to the lowest or earliest deposits. In this work we go from the known culture of the uppermost layers of the mounds back to a period in which conditions were quite different from those under which the recent Indians appear to have lived. (2) The thorough investigation of all cave deposits, whether recent or Quaternary, with particular reference to possible human occupation. (3) A careful study of these Quaternary or recent alluvial formations in which the occurrence of human remains or relics appears to be possible. This comprised a study of many Quaternary formations and the collection in them of all obtainable fossil remains. (4) A careful review of all the evidence relating to the reputed occurrence of implements or human remains in the Auriferous gravels, or other ancient deposits of a similar nature in California.

The result of investigations along the various lines followed in the original plan for the department of anthropology has shown that in a considerable number of cases fragmentary human remains or fragments of stone and bone worked by man have been found in association with Pleistocene deposits in California, but that in every case a very considerable doubt attaches to the occurrence, so that in no instance do we have in California an undoubted occurrence either of human bones or of implements made by man in such association with Pleistocene deposits as to prove the Pleistocene age of the human relics. While remains of man are known in many localities of undoubted Pleistocene age in the Old World, and while an age in years amounting to many tens of thousands and perhaps many hundreds of thousand years can be ascribed to these remains, we have yet to show in California the relics of man's occupation dating back to more than ten or twenty thousand years.

It is possible that man coming from the Old World, the place of origin of the human race, has at various times colonized the North American continent, but was unable to secure a permanent foothold, and because of the brief period of his occupancy has left no ancient relics. Human history may have waited until a comparatively recent time for the occupation of the western hemisphere by man in such force as to make his conquest of the region permanent.

REVIEW OF "MEN OF THE OLD STONE AGE," BY HENRY FAIRFIELD OSBORN

Men of the Old Stone Age: Their Environment, Life and Art. HENRY FAIRFIELD OSBORN. Charles Scribner's Sons: New York, 1915. Pp. 1 to 545; 8 plates, 268 text figures, and 1 map.

It is doubtful whether any field of scientific investigation has proved itself more attractive, both to the amateur and to the trained investigator, than that including the origin and early history of the human family. Within the last decade both scientific and popular magazines of Europe have contained very many interesting, in fact startling, statements concerning recent discoveries in this field of research, but for reasons not clearly understood comparatively little on this subject has come to the general reading public of this country through our own literature. The fact that early events in human history appear to have been staged on a theatre distantly removed from America seems not sufficient to account for our failure to be interested when other aspects of history receive our closest attention. Coming at this particular time of need, Professor Osborn's most admirable presentation of the subject takes an important place in the literature of modern science available to readers with interests ranging from general history, through archeology, geology, paleontology, and all aspects of the problem of anthropology.

The story told in *Men of the Old Stone Age* had its origin in Professor Osborn's personal impressions received on a journey through the regions occupied by early homes of the people of the stone age. It had its first presentation as the Hitchcock Lectures at the University of California before a large and interested audience representing all phases of university life. The interest shown by students and faculty in this course of lectures, and the avidity with which the published volume has been brought into use by university classes, show not only that the subject is one of fundamental interest for all, but that Professor Osborn's presentation and organization of

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the material have given a most fascinating picture of this phase of early history.

Viewed in the light of modern science, the problem of early man is not limited to sequence of cultural and biological changes, but must include an interpretation of the environment in which the human type developed. Many aspects of the whole problem have been considered in a wide range of publications stretching over more than half a century of important research. In certain works the emphasis has naturally been placed upon cultural development, in others upon biologic change or evolution. In an unfortunately large proportion of publications of the first group the ultimate scientific value is much reduced by insufficiency of the data required in determining chronologic succession. In the second group inadequate information as to the nature of evolutionary or paleontologic series in other mammalian groups has often diminished the value of investigations centered upon man alone. In approaching the discussion of men of the Old Stone Age, Professor Osborn frankly confesses that he is not an archeologist, and that for materials representing this phase of the study, he has drawn upon the most eminent authorities, among whom are Hugo Obermaier and Henri Breuil. The geologic succession, especially in its relation to demarcation and the length of the climatic stages, has been based to a considerable extent upon the work of Albrecht Penck, Edward Brückner, and James Geikie.

Very important features of Professor Osborn's book are the exceptionally good foundations for judgment concerning the all-important matters of chronology, and of comparative or historical sequence in skeletal characters. Professor Osborn's broadly founded and widely applied knowledge of the history of mammalian faunas of the Northern Hemisphere in Pleistocene time has given the best available basis for interpretation of chronology and for correlation in study of both cultural and biologic stages. His knowledge of the mammalian paleontologic succession, based upon extended research, has furnished an unusually good foundation for judgment as to value of characters in the human evolution series.

In the opinion of the reviewer, Professor Osborn's book shows an exceptionally good balance of the geologic, paleontologic, and archeologic aspects of the problem. The natural tendency of writers in early stages of development of this subject has been to emphasize special phases, and the value of much important literature has been considerably reduced by failure to correlate the data obtained with that from other fields. We are still far from the stage at which we may assume to put into their true relations to each other the materials representing all aspects of the subject from all geographic stations and from all geologic stages, but great advances have been made in the simplification and interpretation of these records. Professor Osborn's book well represents the present development of the most advanced research, both with reference to extent of material and to correlation and simplification of the essential or significant facts.

With reference to detail of the text of Professor Osborn's book, the author is to be complimented on such excellent organization of the material that it reads as a connected story, and is at the same time most useful for reference on the whole subject of early man.

Concerning the consecutive items of the story of man as set forth in this volume, and especially regarding those parts relating to the least satisfactorily known materials, the writer desires only to express the conviction that the author's views reflect most satisfactorily the trend of thought among investigators most closely in touch with the problems involved. Where vital differences of opinion exist the evidence is presented in such form that the facts are all available. Nothing is more true than that many items in the story of early man are not as yet interpreted to our satisfaction. The book is yet to be published in which every detail satisfies every measurement, but every book is judged on the merit of its contribution or organization of materials needed for the thought of investigators, students, and general readers. Though certain of the materials used by Professor Osborn may be modified to some extent by continued research, the method of treatment and the nature of organization of the subject are such that the book may well continue for a long period as a standard for reference concerning the development of this aspect of scientific work up to the present time.

To the student, either professional or amateur, it must always be true that a word picture, no matter how skilfully executed, can never completely replace the actual visualization of natural objects described. In this respect too great praise cannot be bestowed upon Professor Osborn's volume for the nature, arrangement, and exceptional clearness of the illustrative materials. Maps giving the location of important stations and illustrating changes in geologic history, diagrams showing cross-sections of significant deposits, careful drawings representing important skeletal materials, reconstructions of typical representatives of various faunal stages, and numerous reproductions illustrating the implements and art of primitive man have all contributed to make the perusal of this volume the nearest approach to a journey through the land of Men of the Old Stone Age, and through the museums in which the most interesting remains are now preserved. The book has also been provided with numerous tabulations and diagrams representing sequence of faunas, cultures, and geologic changes. These all assist greatly in reducing the abundant data to their simplest and most significant elements.

The final test of any book is its influence upon the readers who consider it with open mind. The members of the University of California have been particularly fortunate in being the first to hear the message conveyed in this interesting work, and also the first to make large use of the materials in University studies ranging through elementary classes to faculty seminars, and representing a wide variety of subjects related in one direction or another to the problem of history included in the story of early man. The influence of the lectures in their first presentation, and later that of the published volume, which reached an even larger audience than the lectures, has left no room for doubt concerning the interest in this subject presented in the form in which it has been given to us by Professor Osborn. It is well within the limits of conservatism to state that in this particular country no one of the several works in various languages available to us up to the present time has given such an impetus to the study of early human history as has been furnished by *Men of the Old Stone Age*. In the opinion of the reviewer, this field of study will generally be found one of the most attractive aspects of science and of history. We have needed only a statement of the case such as has been given us by Professor Osborn to make possible a larger and better understanding of the subject on the part of the great group of American readers and students, who have normally the deepest interest in all fundamental problems touching man and his environment.

THE BEGINNINGS OF HUMAN HISTORY READ FROM THE GEOLOGICAL RECORD: THE EMERGENCE OF MAN

PART ONE

As now interpreted history means nothing if it does not present connected series in which every part contributes somewhat to the interpretation of all other parts or is in turn interpreted by them. Features of contrast may serve as markers for stages of movement and degrees of change, but the essential interest of the subject is embodied in the idea of continuity or unity.

The concept of evolution as we use it in science is only another form of expression for continuity in historical series presenting sequences of apparently different elements. It represents the idea of growth. It involves rate of development and nature of the forces controlling it. It interprets present conditions in terms of the past, and furnishes to some extent a basis of calculation for prediction of the future.

In the preceding lectures of this series your attention has been directed out over the stellar world, and back in time through certain evident transitions by which the existing stages have been reached. The earth which we inhabit has been shown to you shaping into its present form, and the living world upon it has been passed in review through numberless evolutionary changes leading up to its present highly differentiated, and relatively complicated phases. The mechanism of evolution has also been set forth as we now see it. Astronomer, geologist, paleontologist and biologist have all expressed the idea of growth.

While the passage from stellar to geological evolution has consisted mainly in narrowing of view to special processes, the introduction of an organic or life sequence has involved a most difficult transition, seeming superficially of a qualitative type, and presenting

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one of the great problems barring our way to a full interpretation of nature.

Considering that the evident physico-chemical and biological characters of man resemble those represented in the general scheme of animal evolution, and taking these characteristics together with man's relatively advanced stage of intelligence and constructive ability, it has been natural to think of the human organism as the latest member in a graded series including the stages seen in biological or paleontological history. This might of course be done without assuming relationship between man and nature. It is, however, logical to inquire whether there is not actually full continuity between the biological world and the distinctly human sphere. As humans, no problem of greater fundamental significance faces us in contemplation of the historical or origin sequence in nature.

At a time when our world has just emerged from a conflict involving the making of history of unexampled significance, it may seem that consideration of the beginnings of our story might well wait upon better opportunity for such luxury as speculation regarding an unchangeable past. This view we might well hold were it not clear that future world adjustments, brought immediately before us by the present crises, involve many heretofore little-heeded factors, among which are included those biological aspects of human life and social organization striking their roots down to the lowest strata of history.

Every nation with a clear vision now realizes that with the widely differing peoples of the earth brought into immediate contact by modern rapid transportation, by lightning communication, and by the reaching out of interdependent industries, international difficulties can be settled or prevented only through understanding of the nature, environment and needs of every nation and race. This comprehensive view of the world situation will not be alone the interpretation of the diplomat, of the international lawyer, or of the business man concerned primarily with trade for profit. It will necessarily include perception of the essential similarities and differences of races, understanding of racial and national psychology, of special abilities of peoples for accomplishment in particular directions, and of peculiar needs of races and nations. Together wtih these factors, which have their basis largely in heredity, we must know the true influence of environment, of culture and of language.

The knowledge which we require is such as can be reached only by the fullest attainable understanding of the real nature of every phase of the human type in every aspect of its being. As a part of the required information, it will be essential that we have clearly outlined the background of our entire history, setting before us the evidence as to what we are by showing us how we came to be.

Approaches to Early Human History

Approaches to early human history have been made by many roads; one has been that of the investigator working his way back from present to earlier time by way of documentary history, and finding a lower limit in the beginning stage of written record set down by use of hieroglyphs or alphabets. We have also the approach through work of the philologist and the ethnologist suggesting relationships and origins through similarities of language and custom. Advance to still earlier stages of the human record is made by way of archeology, basing its method in part upon physical superposition of strata in determination of culture sequence. Carrying us still farther down is that aspect of paleontology connected on the one hand with the study of cultures through archeology, and on the other hand basing history upon succession of faunas and floras, and using the sequence of strata worked out by the carefully elaborated technique of the geologist. To these views there must then be added the speculations of the biologist upon relationships of the human family, which naturally follow a broad application of the evolution theory.

There can be no field of science which does not, in addition to its peculiar individuality, represent also the meeting place of other sciences, as for example, chemistry is indissolubly connected with physics and is expressed in terms of mathematics. There are, however, few cases in which the information required for construction of the complete story has remained for a longer period so widely scattered and so sharply divided into the various elements needed for understanding of the subject as have the materials used in constructing the beginnings of human history. As in the development of the relationships of many other sciences, starting from widely separated points, the student of documentary history, the philologist, the archeologist, biologist, geologist and paleontologist have all worked out from their special regions until the widening boundaries overlapping have given us the present field of early human history.

Consideration of that phase of the problem concerning the emergence of man or the beginning of human history is essentially then an archeological and paleontological problem read out of the geological record. The evidence as we know it unquestionably carries us back into records representing geological periods long antedating the present age in the earth's story. Although no sharp distinction exists between the methods of the archeologist and those of the geologist, it seems clear that the interpretations of the geologist and paleontologist with the cooperation of the biologist must be the dominant elements in obtaining our understanding of the earliest stages of human life.

It is the purpose of the two lectures given at this time to deal with that portion of the historical series covered by the *emergence* of man and the stages of his history before the dawn of civilization. While the question is essentially comprised within the realm of geological and paleontological research, it is necessary to consider also such evidence as may be secured from other sources indicating the place of the human type in the natural world, with whatever data may be found to furnish suggestions concerning the origin and ancestry of man. The inquiry concerns specifically a particular portion of actual history. The explanation or causes must be furnished by evidence secured on other lines of thought.

Biological Position of the Human Type

A study of the beginnings of human history, considered from the point of view of an investigator passing in review the evolutionary process, involves the biological relationship of man to other groups or organisms. Before presenting the evidence of human history from the paleontological and geological side it is desirable to set up as a background such information as we have from other sources concerning the possible biological relationships of the human family. These considerations are taken up with a view to determining their value in interpretation of man's place in nature, and the possibility of his growth or evolution out of the natural world. They comprise:

1. The question of existing human differentiation. Do laws of variation, such as are found in other groups of organisms, obtain also among humans? In other words, is a biological scheme of classification naturally expressed within the human group?
2. The problem of geographical distribution of human variations with special relation to the question of origin and classification of such differing types.
3. Problems of comparative anatomy and physiology, including consideration of the question whether man's body is structurally similar to that in the higher animals.

Physical Variation in the Human Group, and Classification of Subgroups

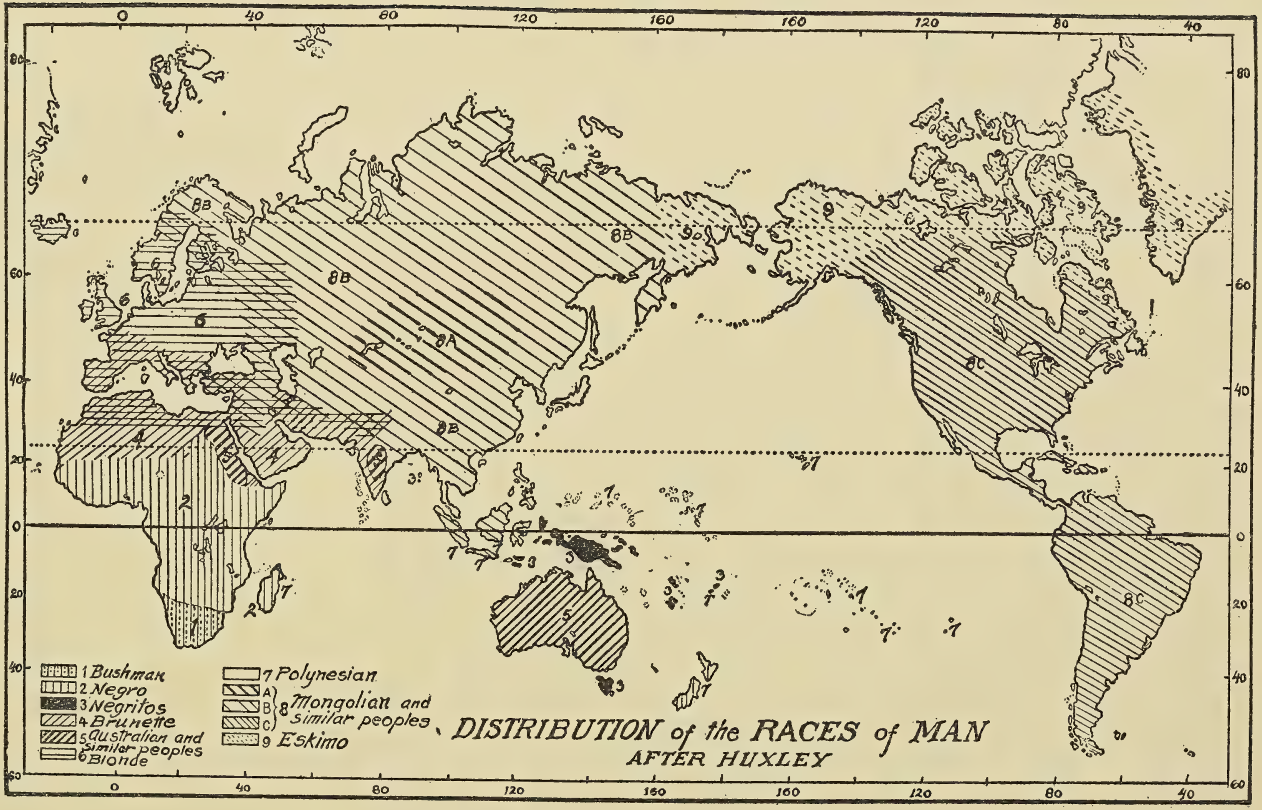
Bringing into review the whole range of variation of the human family in all of its aspects, the differences in structure and in other characters, as color, seem to many biologists comparable to the grades of distinction separating species of horses, wolves, bears, monkeys, and other mammals. There is, to be sure, the unending discussion whether the various *kinds* are to be distinguished as varieties, species or genera; but the settlement of this question is of the same nature as the determination whether the species of one author writing on modern mammals are always comparable with those of another. There may, however, be no difference of opinion regarding existence of these distinctions, or that they represent the natural expression of variation or evolution in these groups of organism.

No biologist coming down from Mars would hesitate to divide the human family into groups comparable to those of other mammals. Though there might be a difference of opinion among the Martians on the question whether certain divisions of the human type should be designated as varieties, species, genera or families, it is probable that the Martians would construct similar classification schemes, their divergence of opinion concerning mainly the question as to nomenclature of the divisions in their similar plans. So the biologists and anthropologists of our own world to-day, without regard to minor differences of opinion, classify the human group, each division with its peculiarities and its assumed relationships, and each perhaps possessing among its peculiarities possibilities for advance of the world interest not open in the same measure to any other group.

Geographical Distribution

Along with other natural relations, the geographical distribution of man presents a most interesting resemblance to the situation obtaining generally among the higher animals. We frequently find that a map showing distribution of the members of a group of mammals or birds represents in fairly clear outlines a classification of the subdivisions such as would be made on the basis of morphology. The forms exhibiting the closest resemblances are geographically nearest, but not in the same place, and those that are most widely separated in characters are generally far apart geographically. The whole scheme of distribution when checked against geological history commonly shows the group gradually radiating from its place of origin and differentiating more widely as the distribution extends. As shown by W. D. Matthew it is not necessarily true that the peripheral types are the most specialized, they may be primitive forms pushed out from the point of origin, but in general wide geographical separation seems to mean wide morphological difference. In the case of man we find this geographical grouping of similar types, the geographical separation of more widely differing groups, and the pattern of distribution corresponding in general to the grouping of varieties or species of the human type according to morphological characters.

In the distribution of human types a most striking suggestion bearing upon the relation of distribution to variation is presented in the physical variation among the inhabitants of North and South America. Although there are between one hundred and two hundred linguistic groups in this area, the physical types throughout both continents are not widely different and are very close to those of Asia, the nearest land. A student of modern mammals, equipped with experience in tracing out the history of distribution of groups, would not hesitate in the case of non-human mammals to state that factors of distribution and variation such as we see in the case of man in America indicate that the organisms concerned have been on this continent such a short time that there has been little opportu-


DISTRIBUTION of the RACES of MAN
AFTER HUXLEY

nity for physical differentiation to take place; and that the American forms are evidently derived from an Asiatic source. It may be desirable to mention in anticipation that the evidence of geological history indicates that man now highly differentiated in the Old World has been present there for a long period, whereas in America, with relatively little differentiated human types, the question as to antiquity extending back as far as the geological period preceding the present is still under vigorous discussion.

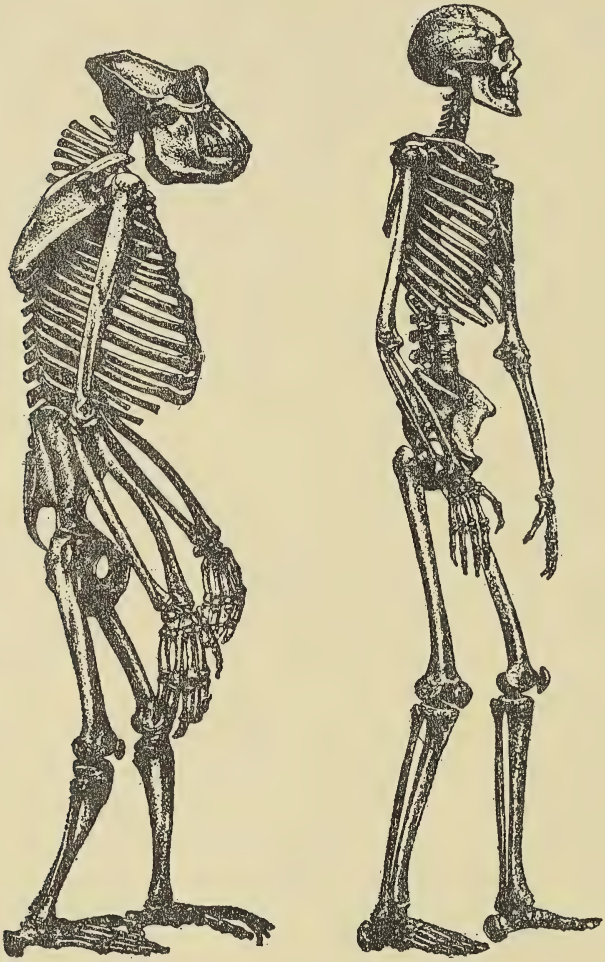
Structural Resemblance of Man to the Higher Animals

The physical characters of man generally resemble those of the apes so closely that discussion of this relationship inevitably resolves itself into a search not for similarities but for differences.

A consideration of features in the anatomy of man assumed to be indicators of relationship requires that reference be made to peculiarities in the development of certain parts of the skeleton which have been held to represent characters of mammals or of reptiles, and to be present in man because of his descent from these lower types. It has been assumed that, among others, such characters are seen in the presence of separate bones representing ribs attached to the neck vertebræ, and present between the pelvis and the vertebral column of man. These elements correspond to normal functioning bones of the reptile skeleton. They originate and develop to a certain stage in man as in the reptiles, but later fuse with adjoining bones.

It is possible that some of these structural features have no relation to the question of ancestory of the human skeleton. On the other hand, as in the case of the ribs lying between the vertebral column and the pelvis, and in the growth of the first two vertebræ, there is every reason to believe that the mode of development corresponding to that of the reptiles in these portions of the body is not related to specific needs of the skeleton of man considered either as completed or in process of growth; but that it represents rather a mode of development initiated in a pre-mammalian stage, and persisting in man by reason of the fact that even at this stage in evolution it offers no distinctly unfavorable features. It should also be noted that the mode of development of these elements seen in man is common throughout the mammals, and is most strongly expressed in those forms which most closely approximate the characters of the reptiles.

The anatomical characters distinguishing us from the anthropoids are generally considered to be most sharply expressed in form and dimensions of the brain and skull, and in form and function of the posterior extremities. It is probably unnecessary to proceed farther than to mention the difference between the brain capacity of less than 600 c.c. in a gorilla bulking larger than a man, and an average of about 1,500 c.c. in a Caucasian male, or a minimum of about 950 c.c. for a female Veddah, one of the lower races. Differ-



Comparison of the skeletons of man and the gorilla, presenting especially marked differences in skull and proportions of anterior and posterior limbs. Skeleton of gorilla to left; skeleton of man to right. Adapted from Ranke.

ence in brain capacity is accompanied by skull distinction of which the most readily recognized character is seen in the relatively large size and prominence of the jaws in the apes.

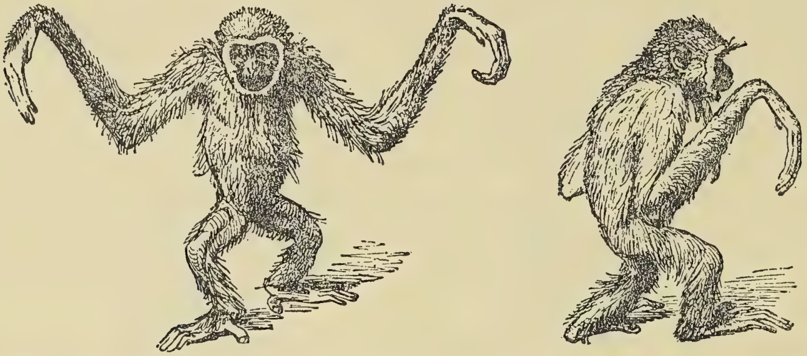
In some respects the difference between man and the apes seems as clearly expressed in the limbs as in the brain, especially since the difference is not merely one of degree, but is in the limbs a distinction of kind and of function. In most apes the relatively long forelimbs are the principal structures for locomotion, which is by swinging through the trees, and to some extent the hands of these limbs serve the head, though the thumb is not generally opposable. The hind limbs of the apes are used for grasping and the feet with opposable first toe serve as hands.

In man the relatively long posterior extremities are used solely for walking. The anterior extremities with opposable thumb of the hand serve the head, and as one among many other functions they may be used for climbing. The opposable thumb is specialized to a high degree and freedom from use in locomotion permits the hands a great development of skill in many directions. In apes there are really four hands, but the pair with opposable first digit is situated on the portion of the body farthest from the head, so that neither pair is advantaged to specialize after the manner of the hand of man.

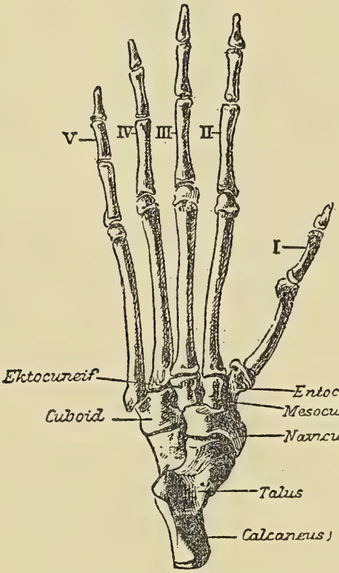
The distal or foot portion of the posterior extremity of both ape and man represents in its fundamental plan the typical extremity of all vertebrates above the fish. It has the same elements arranged in the same order with relation to each other. It is characterized as in normal mammals and reptiles by five digits or fingers in which the inner or first digit corresponds to the thumb and is composed of a smaller number of phalanges or finger bones than the other digits.

In the ape foot the first digit is, as in normal mammals and reptiles, much shorter than the others, but is distinguished by extraordinary mobility including opposability to the other digits as seen in the thumb of the human hand.

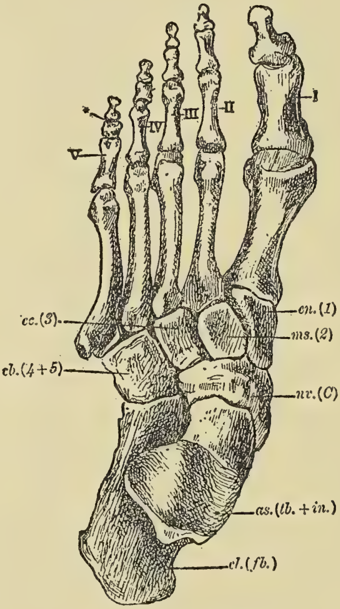
In the foot of man, with the same fundamental plan seen in the apes, we find an extreme modification rarely duplicated in vertebrates, in that the normally short first digit, while retaining the normal number of toe bones for mammals, has been greatly enlarged and elongated until it equals or exceeds the longest of the other digits. It has, moreover, relatively very slight mobility and is not in any sense opposable. The type of modification is so extraordinary among the great number of foot forms known that we must assume for it an important relation to an extraordinary use. This we find indicated in the unusual position of the fore and aft axis of the foot, running obliquely across the foot and through the great



Gibbon. Illustrating extraordinary difference between posterior and anterior limbs. Adapted from Ranke.



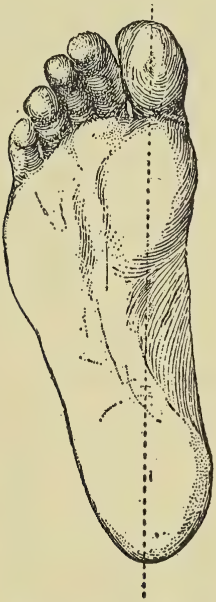
Left foot of chimpanzee
Adapted from Wiedersheim



Left foot of man
Adapted from Wiedersheim

toe, instead of through the middle toe as in most forms, giving us a foot with the toes turned out, the weight of the body being borne very largely upon the end of the inner toe. This extreme modification of the human foot is clearly to be coupled with the specialization of the whole limb for running in a long-legged, two-footed form, standing normally with everted toes.

According to the paleontologist who relates variation in form to variation in use, these peculiar characters of human feet have come to exist through peculiar use, persistently continued for a long period. It seems that we must set the human type off as very unusually modified for the special function of bipedal locomotion so necessary if the hands were to be set free to serve the head.



Sole of human foot. Adapted from Munson

Although in the view of many of the earlier writers the human foot differs but little from that of the apes, a number of investigators have inclined toward the view that the differences seen here constitute one of the strongest evidences indicating a considerable gap between man and anthropoids. The separation has seemed sufficiently wide to indicate that the initiation of changes leading toward the human type of extremity must have occurred at a very remote time, at least as early as the incipient specialization of the ape group tending to produce its peculiar type of adaptation for arboreal life through use of the anterior limbs for swinging or climbing with the hind limbs used for grasping.

In his recent careful review of the subject, Dr. W. K. Gregory takes another view, namely, that the human group may be derived from an anthropoid type which had gone far in the direction of arboreal specialization, and later left the trees and passed through relatively rapid evolutionary stages, producing a long-legged running type with greatly developed big toe. According to Gregory the erect position of man has been made possible by great elongation of arm, permitting fairly erect position of the body in an anthropoid ancestor who rested his weight in some part upon the fore limbs in walking, as in the modern gorilla.

To most students of the problem of structural similarities and differences distinguishing apes and men, the greatest divergences noted are to be classed as differences in degree rather than in kind. This seems in large measure true of skull and brain. The difference in foot structure possibly presents the widest separation and indicates distinction in habits of life conditioned upon locomotion. Should the views expressed by Gregory prove correct, man might conceivably be derived with changes of relatively little significance from forms not unlike the most man-like of modern apes. If other views offer the correct interpretations of structure and of possibilities of modification, the gap is wider and the modern apes will be assumed to represent a type built especially for the trees, while man will be considered as a type long practised in running, long accustomed with free hand to serve a brain given wider opportunity for range of thought. Yet even with this widest gap that we can open the apes are still so near us that with man recognized as a biological type he must, when classified, take his place in the line next to the chimpanzee and the orang.

Conclusions as to Position of Man in Nature

The conclusion which we obtain from a consideration of the biological aspects of the human problem is that physical man may not be separated from the zoological scheme. The sum of evidence from human physical structures gives us an organism dependent upon typical biological processes for its origin, and constructed on the typical mammalian plan. On the basis of general similiarity we are obliged to refer the type to that portion of the mammalian group including the monkeys and apes. Such evidence as we secure from comparative anatomy, interpreted through the study of classification and distribution, suggests that the type of man is built up from a form which was originally reptilian, and has passed through many mammalian stages before reaching its present level of development. We find the human race showing grouped variations of individuals apparently separated from other variations much as are a large percentage of the generally recognized species of many groups of mammalians. We find also that the varying individuals are geographically grouped in a manner paralleling the distribution of mammalian types recognized as species and genera.

From the fact that man is differentiated into clearly separated groups related geographically as are the species of mammals, one might assume that he has been subject to the laws of evolution obtaining in other groups of organisms, and that through a long course of history he has gradually spread himself over the earth, undergoing a process of differentiation concurrent with the extension of his geographical range. In this brief statement, it is not necessary to go farther into consideration of the physiological organization of man than to state that, excepting in minor details, the functioning of this organism is similar to that of the higher mammals of the primate division. The details of physical difference between man and the apes are less than the difference between apes and other groups of mammals assumed to be derived from ancient forms which are considered as also ancestral to the ape-monkey group.

GEOLOGICAL HISTORY OF THE ANTHROPOIDS TO WHICH MAN SHOWS CLOSEST RESEMBLANCE

A most interesting chapter in paleontological evolution, which is necessarily a preliminary to discussion of early human history, is that covering the successive stages of development of the anthropoids to which man shows closest resemblance. If man is considered to be derived from apes, it is necessary to know whether the assumed ancestor existed before man appeared. It is also in many respects as essential to trace the evolution of these hypothetical ancestors up to the branching off of man, as it is to trace man back toward the type from which he is presumed to be developed. Out of the record of anthropoid history it is to be expected that we shall ultimately obtain most important evidence bearing upon the question of man's relationship to the other mammals.

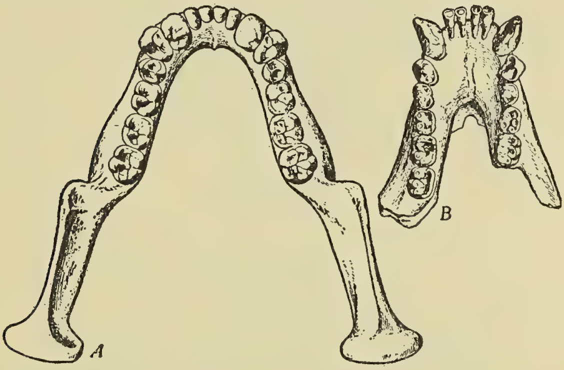
Unfortunately, the available remains of fossil apes are exceedingly fragmentary and include only a limited representation of skeletal parts. Important specimens have been secured from a few localities in Europe, from northern Africa, and, most significant of all, from the great series of Siwalik formations of southern Asia, representing a large portion of the later geological record. The occurrences of this group in the Siwalik beds of northern India are of unusual importance, as the formations are of considerable geographic extent, of extraordinary thickness, of long geological range, the relations of the strata are fairly clear, and there is a splendid representation of a long sequence of mammalian faunas associated with the anthropoids. Study of the Siwalik deposits has been followed through the work of the Geological Survey of India for many years, and most interesting results have been secured, especially by Lydekker and Pilgrim. No remains of anthropoids are certainly known from the western hemisphere.

The primate or man-monkey group was in existence, clearly defined, considerably differentiated, and widely distributed in Eocene time, five periods before the present day, or at the beginning of the stage of dominance of the great mammal group. The anthropoid or ape division of the primates was distinctly represented in Africa in the second or Oligocene period of the mammal age. By the middle of the third or Miocene period, forms having in general the characteristics of the orang and the gorilla are found in Asia, and a representative of the gibbons was present in Europe.

Although the known fossil remains of anthropoids are fragmentary, the available material is sufficient to show distinctly a considerable range of forms in which there are present characters approaching those of the human type, as well as the diagnostic features of the gorilla and chimpanzee. Pilgrim basing his views upon recent studies of the Siwalik collections of India has taken the view that the genus Sivapithecus of the middle Miocene is very close to a line leading to the earliest known human types and also represents the gibbon group.

Of the forms in the middle and late Miocene stage the group of species gathered under the name of Dryopithecus has been held by a considerable number of investigators to stand nearest to man. In his admirable work on the evolution of the primates Dr. W. K. Gregory has recently considered Sivapithecus as closely related to Dryopithecus and a representative of the Simiine or orang-chimpanzee-gorilla group, rather than of the gibbons. The characters of the dentition and form of the jaw of Sivapithecus and Dryopithecus approach closely to those of the earliest types referred to the human group.

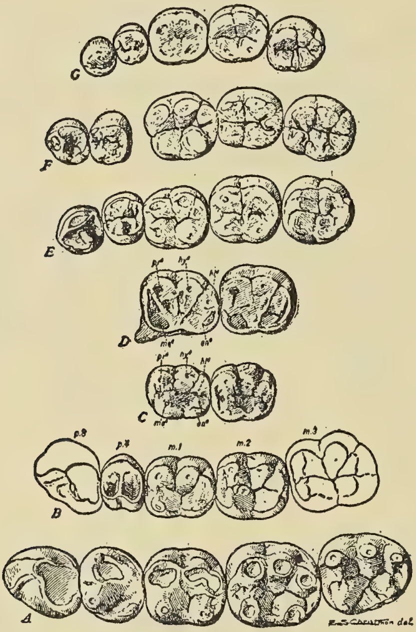
Taking the sequence of anthropoid forms as we know it, we find that in the earlier portion of Cenozoic time only relatively simple types are known as Parapithecus and Propliopithecus in which there are foreshadowed characters of both the typical anthropoid and gibbon types. In middle and late Miocene the gibbon becomes distinctly separated from the true apes, and there appears a group of several genera including characters of orangs, chimpanzees, gorillas and humans. As we proceed through the Cenozoic these groups become sharply defined, until by the end of the Pliocene they are clearly separated as at the present time, and in their development have passed through stages from some one of which the line of evolution to man many well have originated.



Comparison of *Sivapithecus* and *Dryopithecus*. Lower jaws, upper view, multiplied by one-third. *A*, *Sivapithecus indicus*, provisional and partly hypothetical restoration after Pilgrim; *B*, *Dryopithecus fontani*, after Branco. (Figures adapted from W. K. Gregory.)

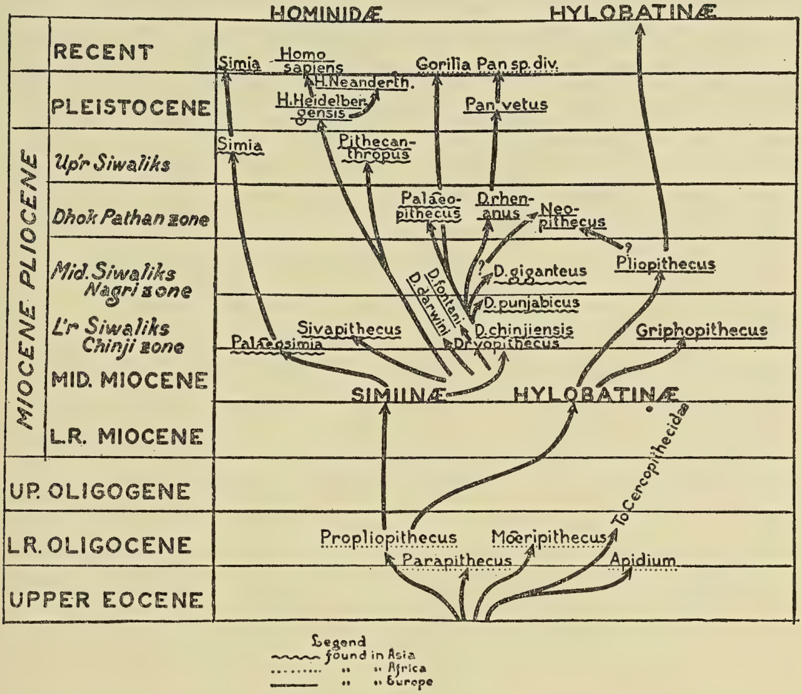
A number of exceedingly fragmentary fossil specimens from America doubtfully referred to the anthropoid group are generally presumed to represent members of the Suidæ or pig family. Inasmuch as we are just beginning to obtain a knowledge of the Pliocene, which is the critical period in consideration of earliest human history, and since the American assemblages in which the doubtful anthropoids appear are in many respects close to faunas of Asia and Europe in which anthropoids occur, it is not impossible that members of this group may yet be recognized in the latest Miocene and Pliocene of North America.

The interesting views of Dr. Florentino Ameghino concerning the possible origin of man by way of evolutionary stages leading through the South American platyrrhine monkeys seem not to be founded upon good logic, as these forms are fundamentally distinct in dentition and general skeletal structure from the Hominidæ or human family and from the whole old world group of anthropoids.



Comparison of cheek teeth from the lower jaw of primitive men and anthropoids, crown views about three quarters natural size. *A*, gorilla; *B*, *Sivapithecus indicus*, after Pilgrim; *C*, *Pan* sp., after Miller; *D*, *Pan vetus*, adapted from A. Smith Woodward; *E*, *Homo heidelbergensis*, adapted from Schoetensack; *F*, *Homo sapiens*, molars of old female Australian black; *G*. *Homo sapiens*, from a Strandolooper Bushman. (Figures adapted from W. K. Gregory.)

Of all the remaining unsolved problems of evolution one of the most important seems to rest in the working out of the later paleontologic history of the anthropoids, particular consideration being given to possible relationship of these forms to the earliest humans. As nearly as we can now determine, the Asiatic region has seen a large part of the evolution of the apes, and contains also the oldest known remains of man. If man has been derived from anthropoids, the chain of missing links required to establish this biological relationship is presumably to be found there.



Geological succession and provisional lines of descent of man and apes. (After W. K. Gregory.)

The 16,000-foot thickness of the Indian Siwalik series presents a most important volume of record in which anthropoid history is written, and no conditions for preservation of remains are more favorable than those of this region. It is not too much to expect that the next ten years of concentrated, well-organized effort in the Asiatic region will furnish undreamed chapters in history giving early tendencies of evolution toward human characters, and evidence on the structure, relationships, habits and environment of earliest man. The undertaking will require much energy and large support, but when other problems of immediate urgency have been satisfactorily settled, it is to be hoped that this work may be carried through. It must be done by more intensive collecting in the known areas, and by a wide range of studies through other occurrences of the late geological formations found over large districts of the Asiatic region. There seems no doubt that some of the most important sources of material have as yet scarcely been examined. Concentrated effort by cooperation of a number of research institutions, or through considerable endowment by one institution operating through a series of expeditions would unquestionably contribute very largely to our knowledge of this most interesting phase of the evolution problem.

THE BEGINNINGS OF HUMAN HISTORY READ FROM THE GEOLOGICAL RECORD: THE EMERGENCE OF MAN

PART TWO

Geological History of Man

Having considered the biological position of man and the possibility of his ancestry leading out of the evolution of presumably inferior, and certainly older primate groups, we are in a favorable position for discussion of the earliest evidences of man himself; but before entering upon consideration of the specific problem of human history, it is well to bring to mind certain of the most fundamental conclusions obtained in an inspection of the wide field of history of other living creatures. To one who reads this story, the evidence of the geological and paleontological series amounts to a demonstration that our available records of life in the broadest view count up to many tens of millions of years at the least, and possibly reach to hundreds of millions. We see also that in this time the record shows life to have been in an almost continuous state of change; that the life of each period exhibits closer resemblance to that of the periods immediately preceding and following than to the more remote divisions of time; and that series of forms with certain common characters but differing in grade of specialization generally tend toward greater specialization from earlier to later time. The manner in which the modifications take place may not always be understood, and the paleontologist may admit his ignorance of the causes, but the evidence of continuing change and advancing specialization in series of presumably connected or related types seems reasonably clear.

Well within the generally accepted record of the geologist, and forming a part of the life succession of the paleontologist, the human

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Delivered before the National Academy of Sciences in April 1918, as the second lecture of the sixth series on the William Ellery Hale Foundation. *Scientific Monthly*, vol. 10, no. 4, pp. 321–342, April 1920.

element appears, taking its place in the life sequence and raising, whether we desire it or not, the question of man's inclusion in the general scheme of evolution, or of his relation to the other biological series for which we have traced a long history and through which we seem to see running the thread of continuity.

From what we have seen in our paleontological record there is every reason to believe that there was a long period in which generalized members of the mammalian group were widely distributed and man had not yet appeared. Unless we take the view that man is the product of special creation, built upon lines similar to those of other organisms, we naturally assume that his origin is found in the earlier less specialized type, and by way of an evolutionary process not unlike that which has determined the development of other mammalian forms by modification of types already existing.

THE EARLIEST REMAINS REFERRED TO THE HUMAN TYPE

Discovery of Pithecanthropus

Probably no paleontological contribution published has furnished the basis for more extended and more critical discussion than the paper of Eugene Dubois published in 1894, describing a remarkable tooth, a skull-cap and a thigh bone, found in deposits of considerable geological antiquity on the island of Java. These specimens, presumed to represent a single type, and probably one individual, were first referred to by Dubois in 1892 as *Anthropopithecus erectus* or the erect man-ape, assumed to represent a transition between man and the apes. After having with most commendable patience investigated his material for three years, Dubois published his now classic memoir. In this paper the specimens were referred to as Pithecanthropus, or ape-man, this generic name having been used by Haeckel in 1868 for a hypothetical creature assumed to walk erect, and to have higher mental development than the anthropoids, although not yet attaining to the formulation of speech.

Following the work of Dubois, extensive excavations initiated by Frau Selenka were carried on in 1907 and 1908 on the site of the occurrence of the type specimen. These important studies added much to our knowledge of the formation in which the Dubois specimen was found, and of the fauna associated with it, but did not contribute additional Pithecanthropus remains.

Occurrence and Associated Fauna

The specimens referred to Pithecanthropus all exhibited approximately the same mode of preservation, which is similar to that of the extinct types of mammals found in the same strata, and which have clearly been buried in process of accumulation of the formation. There was no evidence indicating intrusion or burial of these remains in the formation since accumulation, and the relation of the Dubois specimen to the stage of geological time represented by the deposits containing the mammalian fauna is not seriously questioned.

Some doubt has been expressed, however, whether the skull-cap, the femur, and the teeth belong to the same individual. The first tooth and the skull-cap were found in 1891 only about three feet apart. The femur, discovered the following year, was situated nearly fifty feet from the location of the skull. Inasmuch as the femur is by some considered quite human in aspect, while the skull-cap is assumed to be pre-human, question has naturally been raised as to the relation of these elements to each other. On the other hand, the fact that skull, teeth and thigh bone occurred approximately together, with similar mode of preservation, and with peculiar characters differing from those of all known anthropoids and humans, is considered by many as evidence distinctly favoring the view of Dubois that the specimens all represent one species and one individual. It will evidently not be possible to settle this question with full satisfaction until further occurrences of remains of this most interesting type are discovered.

The Pithecanthropus specimens were found in a formation composed in large part of volcanic tuff. It was considered by Dubois as a river accumulation and was assumed by him to have a total thickness of over 1,000 feet. The results of the Selenka expedition indicated that the so-called Pithecanthropus layer, containing bones of many extinct animals, owes its origin to the gradual working over of ash beds formed through eruption of great volcanoes near at hand. In the course of the eruption many animals were destroyed and the remains buried in ashes. Rain wash worked over the ashes and the entombed bodies of animals. The bones washed out were later accumulated at points where swamps or comparatively level stretches in the stream stopped transportation of heavy objects by slowing of the current.

The particular layer in which the Pithecanthropus specimens were discovered was found by Dubois and by the Selenka expedition to contain a large number of remains of mammals, representing at least thirty species. These include the pre-elephant, or Stegodon, which is ancestral to the modern elephant, also cats, hyenas, rhinoceros, tapir, pig, hippopotamus, deer, buffalo and monkeys. Along with the mammals was a considerable variety of reptiles, among which were crocodiles, gavials, lizards, snakes and turtles.

The mammal fauna of the Pithecanthropus beds resembles in many respects that of the Java region of the present day, but practically all of the species are extinct. Certain forms, as Stegodon, are generally characteristic of the Pliocene, the second period preceding the present. The mammal assemblage as a whole is very close to that of southern Asiatic formations representing a stage near the close of the Pliocene, as seen in certain of the later levels of the Siwalik series in India. As mammal faunas are generally short-lived in the geological sense, there seem good reasons for considering that the beds containing Pithecanthropus and the associated mammal remains were deposited at a period approximately the same as the late Pliocene or the early part of the next stage, the Pleistocene, as recognized in other formations of which the age has been clearly determined (see Fig. 7, page 1602).

Suggestions regarding age of the beds have also been made by Blanckenhorn on the basis of climatic conditions obtaining during accumulation of the deposits. Abundant plant collections secured in the formation containing Pithecanthropus indicate to practically all investigators who have examined them a much more humid climate than that now found in this region, and perhaps a temperature five or six degrees colder. Considering the Glacial Epoch to have been a time of relatively high humidity, Blanckenhorn believed the available evidence indicative of a time stage for the Pithecanthropus beds corresponding approximately to the first or Günz stage of glacial time, or near the beginning of the Pleistocene period.

Nature of Remains

Study of the remains of Pithecanthropus has been carried to an extreme of detail rarely reached in investigation of other known specimens. It is only regrettable that this research, so far as it has been done by workers other than Dubois, has been based largely upon casts of the originals rather than upon the specimens themselves.

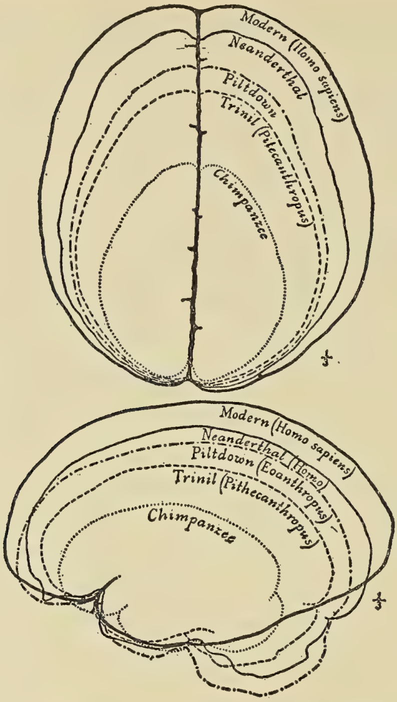
The *tooth* first found is of extraordinary size, and quite different from the corresponding third upper molars of human beings. It either represents a large individual, or an individual with relatively large and heavy teeth.

The *skull-cap* has been examined from almost every possible angle of physical or mental vision by a great group of investigators, and is by common consent a most unusual type, bearing in general the characters of a human being, but more beast-like than any human species, recent or extinct. The vault of the cranium is low, and the arch is flat both on the forehead and on the back of the skull. The eyebrow ridges are very prominent, as in the apes, and the skull is narrow behind the eyes. The brain capacity is lower than that of normal human types. Measurements of the cranial capacity given by Dubois have approximately 900 cubic centimeters, while the corresponding measurement of anthropoids rarely reaches 600 c.c., and of male Caucasian humans approximately 1,500 c.c.

From the interpretation of this specimen, it is evident that Pithecanthropus represents a type previously unknown in either the human or the anthropoid group. It differs from the apes in its larger brain capacity coupled with reduced musculature relating to the jaws. It differs from man in its lower brain capacity and more beast-like contour of the skull. If there is justification for the assumption that the large teeth pertain to the same individual as the skull-cap, there seems sufficient warrant for accepting an ape-like reconstruction of the face with the large protruding jaws needed to support large teeth.

Many restorations of the skull have been made, among which one of the most interesting is that by Dubois, showing the low-vaulted skull, prominent eye ridges, heavy jaws, and protruding facial region.

The *thigh bone*, found at the same level with the skull, resembles the corresponding bone of typical humans in some respects more closely than the skull resembles the cranium of human types. It approaches the human femur and differs generally from that of apes in its length, slenderness and straightness of shaft, as in other minor details. It is in fact more slender in some respects than the thigh bone of modern races. Resemblance to the femur of modern



[Figs. 1–3, 6, 8–13, 15, and 17 are at end of paper.]

FIG. 4. Diagram showing outlines of the Pithecanthropus brain compared with that of the chimpanzee and certain human types. Upper figure, outline seen from above; lower figure, outline seen from side. After Osborn, "Men of Old Stone Age," Charles Scribner's Sons.

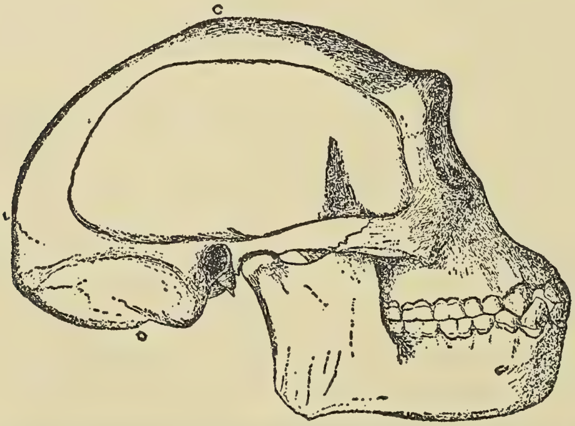


FIG. 5. Reconstruction of the Pithecanthropus skull, × $\frac{1}{3}$. After E. Dubois.

man is not, however, in any sense complete. Dubois has called particular attention to the more nearly circular cross-sections of the bone, and to distinct differences in certain important areas of muscle attachment. To a slight extent the peculiarities of the Pithecanthropus femur resemble those of the gibbon, but they do not correspond fully to gibbon characters.

This thigh bone can not conceivably belong to an animal of the ape type. The form of the shaft and the nature of the articulations at the distal end are different from these features in apes. They show that the animal evidently walked with a degree of erectness comparable to that of typical humans, and that it must have possessed a length of limb and extent of stride in locomotion comparable to that of modern forms. This character of specialization for running or walking is not naturally combined with specialization of the anterior limbs for climbing, and we may safely assume shortness of arm like that of humans, and different from the type of limb in arboreal anthropoids.

Dubois and others have considered that the degree of deviation in form of the femur from that of normal modern man and from the apes corresponds approximately to the extent of difference between the skull-cap of Pithecanthropus and that of both typical apes and typical men.

Systematic Position

To the gratification of a large group of scientists, not long after publication of his memoir on Pithecanthropus, Dubois appeared with his specimens before the Zoological Congress at Leyden, where there occurred one of the most interesting discussions on the history of man that has ever taken place. Divergence of opinion as to significance of the remains lay largely in the question of classification. Five of the noted authorities, including Virchow, considered the animal to represent an ape; seven, including Cunningham, Lydekker and Topinard, considered it a man; and seven others, including Dubois, Manouvrier, Marsh and Haeckel, considered it a transition form.

With the wide knowledge of structure of man and of apes possessed by all of the eminent students whose opinions were expressed, it is clear that the essential difference lay in the definition of diagnostic characters of humans and apes. It is also evident that opinion of the group as a whole indicates the intermediate position of Dubois's find between typical humans and typical anthropoids. Centering upon the controversy over Dubois's specimens there has developed a discussion as to definition of human and anthropoid characters. There seems now to be practical unanimity of view that the essential distinctions lie in possession by man of somewhat greater brain capacity, erect position, length of limb, freedom of arm

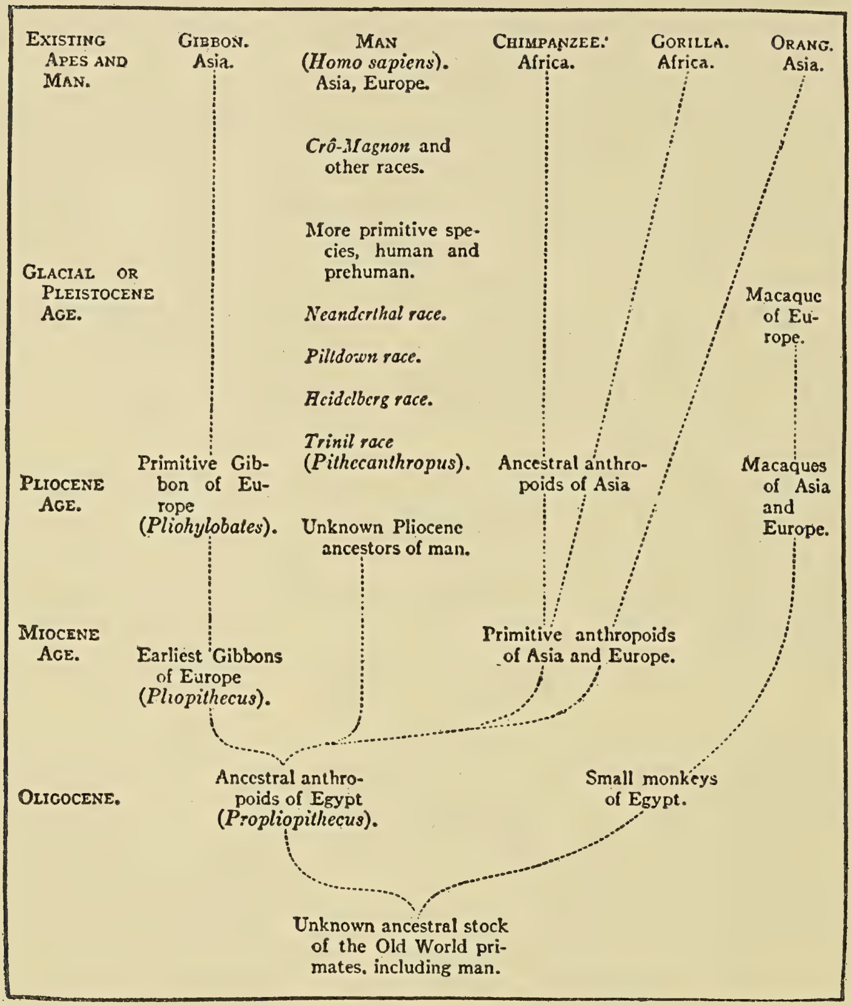

EXISTING APES AND MAN.
GIBBON. Asia.
MAN (*Homo sapiens*). Asia, Europe.
CHIMPANZEE. Africa.
GORILLA. Africa.
ORANG. Asia.
Crô-Magnon and other races.
More primitive species, human and prehuman.
GLACIAL OR PLEISTOCENE AGE.
Neanderthal race.
Piltdown race.
Heidelberg race.
Macaque of Europe.
Trinil race (*Pithecanthropus*).
PLIOCENE AGE.
Primitive Gibbon of Europe (*Pliohylobates*).
Ancestral anthropoids of Asia
Macaques of Asia and Europe.
Unknown Pliocene ancestors of man.
MIOCENE AGE.
Earliest Gibbons of Europe (*Pliopithecus*).
Primitive anthropoids of Asia and Europe.
OLIGOCENE.
Ancestral anthropoids of Egypt (*Propliopithecus*).
Small monkeys of Egypt.
Unknown ancestral stock of the Old World primates, including man.

FIG. 7. Outline of the evolution of anthropoid apes and man. After Osborn, "Old Stone Age," Charles Scribner's Sons.

and hand from locomotion, and perhaps in possession of speech with sentence construction. These characters are contrasted with the smaller brain, more prominent face, relatively short grasping posterior limbs, and long anterior limbs used for climbing, seen in apes. Judged according to this definition, it is evident that Dubois's specimen represents a stage just above the middle territory between man and the apes. The animal seems particularly human in its limbs and pre-human, with strong anthropoid tendencies, in the skull.

Reconstruction

A reconstruction of the skeleton based upon skull-cap, teeth and femur of Pithecanthropus makes necessary the organization of an animal with upright position and long straight limbs. There can be little doubt that with this structure of limb the foot must have been much as in modern man and the great toe much enlarged. With such limbs, the anterior extremities would be released from the burden of work in locomotion and come to serve the head alone. The large teeth make heavy jaws and a prominent face almost a certainty. The small brain case and prominent rims of the orbits give the combination of pre-human and super-anthropoid characters required by the long-sought missing link. If, as Dubois assumes, we are correct in relating these three classes of characters in one skeleton, there is little required to give the picture of a transition form as visualized by those who have foreseen the discovery of an ancestor of man coming out of the animal world.

Although the remains of the Java man are most unfortunately fragmentary, it is worthy of note that the long discussions which have focused on these specimens have left us with a remarkable unanimity of opinion as to the nature of the type. It is one of the most significant facts in the whole range of paleontological study, that these earliest known remains referred to the human group seem without question to represent the type farthest from modern humans and nearest to the anthropoids. The gap between the modern man and the modern apes is not fully bridged. It is perhaps worth stating that it will be difficult to define "fully bridging." The views as to what would constitute transition or "exactly intermediate stage" would probably vary with different investigators. It is, I think, quite certain that for the particular stage of geological time in which it lived Pithecanthropus comes as near as we could well imagine to the expected intermediate form.

The Heidelberg Jaw

Occurrence and Associated Fauna

The second and perhaps more important find of the two earliest known occurrences of remains referred to the human group is that known as the Heidelberg jaw. This specimen was obtained by Schoetensack, as the reward of twenty years persistent and continuous effort to learn whether traces of man might be found associated with the remains of extinct mammals at a locality in the Elsenz Valley not far from Heidelberg. From a sand pit Schoetensack had obtained many remains of extinct mammals of a stage sufficiently late in geological time to come within the assumed period of human evolution. Schoetensack had repeatedly impressed upon J. Rösch, who worked at the pit, the importance of a possible find of human remains, and the desirability of immediate and careful handling of any specimens suggesting man, should they appear. When in 1907 one of the workmen shoveled out a jaw of human type from a depth of approximately seventy-nine feet, the arrangements of long standing were favorable for rapid and trustworthy determination of the conditions of occurrence of this, one of the most remarkable known relics furnishing information bearing upon early human history.

The pit in which the famous jaw was found is cut into deposits consisting mainly of a formation known as the Mauer sands. At this locality the beds are about eighty-two feet in thickness. Between twenty-five and thirty feet of the upper portion of the deposits represent two formations known as loess. Below this upper section are the Mauer beds consisting mainly of sand and gravel. The human jaw was found only a little less than three feet from the base. The layer in which it was discovered was mainly gravel which was found to contain remains of extinct mammals characteristic of the Mauer beds. The condition of the undisturbed layer from which the jaw was taken leaves no room for doubt that all of the fossil remains, including the human jaw, were deposited at the same time with the sand and gravel making up this lowest portion of the formation.

The fauna found in the formation comprises not less than fourteen mammalian species, including the Etruscan rhinoceros, a species of horse, a primitive elephant (*Elephas antiquus*), a large lion (*Felis leo fossilis*), and remains of bear, deer, pig, and bison.

Schoetensack held that the Mauer fauna showed relationship to the early glacial or inter-glacial forest bed of Norfolk, as also to the Pliocene. The rhinoceros and the horse were considered especially significant of the earliest Pleistocene or Pliocene. Schoetensack placed particular stress upon the possibility that the jaw was the earliest authentic skeletal representative of the human group. Other investigators have considered the formation in which the Heidelberg jaw was found as considerably later and representing the second or Mindel-Riss inter-glacial stage.

Description of Remains

The Heidelberg jaw undoubtedly constitutes one of the most interesting remains of early man thus far discovered. In comparison with all modern human types, it is characterized by its unusual size, lack of protruding chin, great strength and thickness of the body of the jaw, and unusual width of the area for the attachment of the muscles used in mastication. It is also characterized by the extraordinary form of the inner side of the anterior region of the jaw in an area marked by the attachment of certain muscles having an important relation to movement of the tongue in speech. The teeth are large, but not relatively large compared with the size of the jaw, and are notably human in practically all characteristics. While the jaw without the teeth might not have been called human, the teeth without the jaw would certainly have been assumed to represent a human type not differing greatly from known species.

The teeth are characterized by strength of the roots and large size of the pulp cavities; but considering their relation to the peculiar primitive type of jaw in which they are situated, the most striking characteristic of the dentition is probably the small, distinctly human canine. Comparison of the human dentition with that of the apes brings out the fact that humans are distinguished by limitation of the canines to such dimensions that the crowns of these teeth show approximately even length with those of their neighbors. In the apes, as in many other groups of mammals, the canines are very prominent, projecting far beyond the level of the neighboring teeth, and having an important function in tearing food or in fighting. It has been assumed that primitive humans and intermediate types between man and other mammals would naturally be characterized by somewhat larger canines than those of modern species. In a jaw showing the massiveness, strength and primitiveness of the Heidelberg specimen, it would be natural to expect a canine of somewhat greater size than that of modern human beings, whereas, as indicated, this tooth is here reduced to dimensions comparable to those of advanced modern types. It seems, therefore, that reduction of the canine to dimensions comparable to those of other teeth in the front of the jaw may be one of the most significant characteristics of early man.

As shown in comparison of an Eskimo, the Heidelberg jaw, and a chimpanzee, the combination of characters in the Heidelberg specimen is more like that of the anthropoids than is the combination known in other forms referred to the human group. While the dentition in general is distinctly human, the size of the teeth, compared with those of many modern types, the heavy roots and the wide pulp cavities present characters which point toward an ancestral form resembling the anthropoids in some measure.

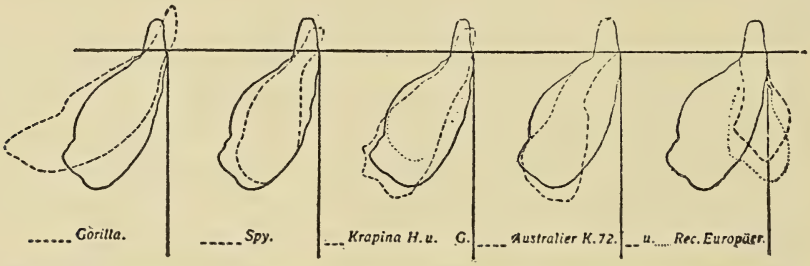


Fig. 14. Comparison of vertical sections through the chin region of the lower jaw. The sections of the Heidelberg jaw are drawn in heavy line. The jaws with which comparison is made are indicated in broken lines. After Schoetensack.

In the configuration of the inner side of the jaw, there are strong evidences indicating that the musculature was different from that of modern man endowed with peculiar characters of the tongue related to speech.

The upper dentition and skull of the Heidelberg man have been reconstructed with great care by Dr. J. H. McGregor, and show a form resembling that of Pithecanthropus in many respects, but somewhat less ape-like. The teeth are smaller than those of Pithecanthropus. The face was probably less prominent and the brain capacity presumably greater.

Significance of the Heidelberg Jaw

The stratigraphic position of the beds from which the Heidelberg or Mauer jaw was obtained has not been questioned. The associated fauna has been known at a considerable number of other localities, so that the occurrence of this specimen is defined as that of a form living in middle or early Pleistocene time, with certain suggestions of Pliocene stage. The age of the Pithecanthropus specimen has been the subject of much discussion, and is considered by some to represent a stage only a little earlier than that of the Mauer jaw. The association of the Pithecanthropus skull-cap, teeth, and femur as parts of one individual or one species has also been questioned. While it may be that the Java specimens represent the same individual, it is also within the range of possibility that they represent two or three distinct types. Though great interest attaches to the discovery of Pithecanthropus, and to the speculations concerning the nature of the creature or creatures represented by this find, it is possible that the unquestionably primitive Mauer jaw, occurring in undoubted association with an early Pleistocene fauna and in a somewhat more definite geological situation, represents the most important and perhaps the earliest of the known human remains.

Possible Traces of Artifacts Produced by Earliest Humans, the Eolithic Culture

Assuming that two of the essential characters separating the human group from the anthropoids are found in the freeing of the anterior extremities to serve the head and in the development of intelligence to make possible a wide variety of uses for the anterior extremities, one naturally considers the making of implements or artifacts as a characteristic which should be distinctive of humans. Question has therefore arisen whether the Pithecanthropus and Heidelberg types had reached a stage at which natural objects were regularly worked into artificial forms.

The Selenka expedition secured, along with other fossil remains found in the Pithecanthropus beds of Java, a considerable number

RECENT			NEOLITHIC	*Present Fauna.*	Robenhausian. Campignian and Tardenoisian. Tourassian.
QUATERNARY	FOURTH GLACIAL PERIOD	Retreat.	PALEOLITHIC PERIOD	*Fauna of the Reindeer.*	Tarandian Industry.
		Advance.			
	THIRD GLACIAL PERIOD	Retreat.		*Fauna of the Mammoth (Elephas primigenius).*	Eburnean Industry.
		Advance.			
	SECOND GLACIAL PERIOD	Retreat.			Mousterian Industry.
		Advance.			Acheulian Industry. Chellean Industry. Mesvino-chellean or Strépyan Industry (Strépy, Belgium).
	FIRST GLACIAL PERIOD	Retreat.	EOLITHIC PERIOD	*Fauna of Elephas antiquus.*	Mesvinian Ind. (Mesvin, Belgium). Reutelo-mesvinian or Mafflean Industry (Maffle near Ath, Belgium.
		Advance.			Reutelian Industry (Reutel, Belgium).
TERTIARY	PLIOCENE	Upper.		*Fauna of E. meridionalis*	Ind., Cromer Forest Bed (Norfolk). Industry of Dewlish (Dorset). Industry of Saint-Prest (France).
		Middle (Glacial.)			Industry of the Chalk Plateau (England).
		Lower.			
	MIOCENE	Upper.		*Fauna of Dinotherium*	Industry of Puy-Courny (France).
		Middle Lower.			
	OLIGOCENE	Upper.		*Fauna of Acera-therium*	Industry of Thenay? (France).
		Middle Lower.			
	EOCENE				

FIG. 16. System of chronology in the Stone Age. After MacCurdy, adapted from Rutot

of bone fragments showing peculiar fracture and worn points suggesting use by primitive man. Blanckenhorn and others who examined these specimens carefully were, however, of the opinion that they might have been produced by fracture of bones carried in a stream or broken by beasts, and that they were not certainly to be attributed to the work of the hominid represented in these strata.

By far the largest representation of evidence suggesting the use of implements by primitive man-like forms, near the period of transition from ape to man, is that furnished by the great quantity of flaked flints obtained from strata ranging from Pleistocene down through the late and middle Cenozoic formations of western Europe. The specimens, representing what have been assumed to be the first artificial implements, have been designated as *eoliths*, or the work of the dawn period of implement making. Especially through the work of Rutot, a considerable variety of flint forms coming from deposits ranging back through the period of Pithecanthropus and the Heidelberg man to older time stages have been interpreted as early efforts at preparation of artificial tools.

It is to be assumed that the earliest stone implements used by man were fragments which in their unmodified form were somewhat better fitted for the use of his hand than other more unwieldy or irregular pieces. Presuming that man early learned the cutting power of a rock, it is probable that fragments with sharp edges naturally produced were used at times in place of those with rounded contour, and that specimens thus used and fractured by use may have been found to have an advantage over weathered rocks naturally broken. This may have led to artificial preparation of such broken stones. There should, therefore, be an intermediate stage between unworked natural objects and the earliest tools purposely produced. From the materials representing this type, it would be exceedingly difficult to obtain evidence as to the way in which the objects were formed.

No scientific controversy in Europe in the last decades has been more warmly contested than that over the artificial or non-artificial character of the eoliths or broken flints from formations of approximately Pliocene age, and in the zone in which one might expect the beginnings of implement making.

Among classic localities for these flints is that of the Kent Plateau, where, near Ightham in the south of England, Mr. Benjamin Harrison through many years has collected a wide range of flint forms from deposit assumed to be of Pliocene age. These eoliths occur in a red clay formation which lies across the edges of several upturned formations of considerable antiquity. Through this plateau there has been cut the valley of the Thames River. In sculpturing out the modern topography, various stages in the cutting of the valley along the streams have left terrace deposits on the banks, in which considerable numbers of flint implements have been found. In the lower levels bordering the valley, the flints represent stages in the history of implement making corresponding to the middle Pleistocene of western Europe. In the uppermost level representing the stage before the cutting of the valley, eoliths are obtained and the Pleistocene implements are not represented. There is, then, an historical sequence in the implement making of this region beginning with the stage of the eolith of the upper plateau, and grading through the more advanced stages of implements in the lower terraces.

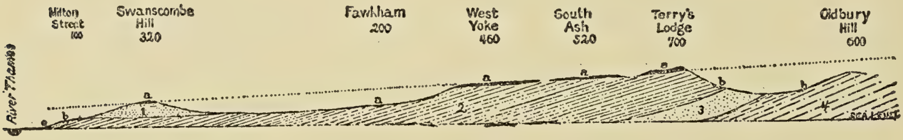


FIG. 18. Section from the Thames to Oldbury Hill near Ightham, Kent, England. After MacCurdy, adapted from Prestwich. 1, Tertiary; 2, Chalk; 3, Upper Greensand and Gault; 4, Lower Greensand. *a*, Red clay with flints—eoliths. *b*, Upper valley gravel—palæoliths. *e*, Low-level valley-gravels—palæoliths.

The eoliths of the Kent Plateau correspond to a period not later, and probably earlier, than that of Pithecanthropus, and certainly older than that of the Heidelberg man. It is not improbable that flaked flints of this nature were used by both of these primitive human types. Whether the flints of the Kent Plateau were implements and whether their origin was through artificial human production is difficult to determine. The possibility that they grade insensibly into flaked flints of a type which may have been produced without the intervention of man, does not prove that their form was not due to human influence, and that they were not actually used by man. On the other hand, there is much evidence to indicate that many of the flints of these eolith beds may have been formed without human assistance.

Conclusions Regarding Significance of Earliest Human Remains

In concluding this phase of the discussion relating to the earliest traces of beings of our human group, it may be desirable to view in the large the data thus far assembled.

We have seen that remains of man-like forms are not limited to deposits of the present period nor are they found in all formations of the geological succession. We find the earliest evidences indicating the presence of man appearing at that particular time, and not before the time, when evolution of the group of animals most closely resembling us had reached a stage near to the human type.

We find the earliest humans represented as a part of the normal life of the earth in a period so remote that in our calculation of its date a thousand years seems only as a day. Pithecanthropus and the man of Heidelberg were long dead, and had become ashes of a bygone age, before the world saw the beginning of many extended series of events, which changed the form of continents, shifted the earth climate back and forth from arctic to temperate in changes of the Glacial Epoch, and passed over the earth long processions of living generations each in turn enjoying its hour of geological timd and fading out into the night of history. Although of these most ancient humans the earliest preserved traces are very faint, we find them adequate to show that at the time in which they lived our race was represented by beings set off from other primates by their erect bodies, long-striding limbs, hands that were free to build, and a brain that began to plan. And yet we find these forms more beast-like and more anthropoid than any type of man at any later time.

So far as our evidence goes, it meets the requirements of those who assume the emergence of man from the animal world in the same manner in which innumerable other organic types have arisen in the long life record as we know it.

The reading of the full story of the advent of man is still to come, and the task of deciphering it will go on into coming centuries. With this must proceed also interpretation of the subsequent stages of man's growth or evolution.

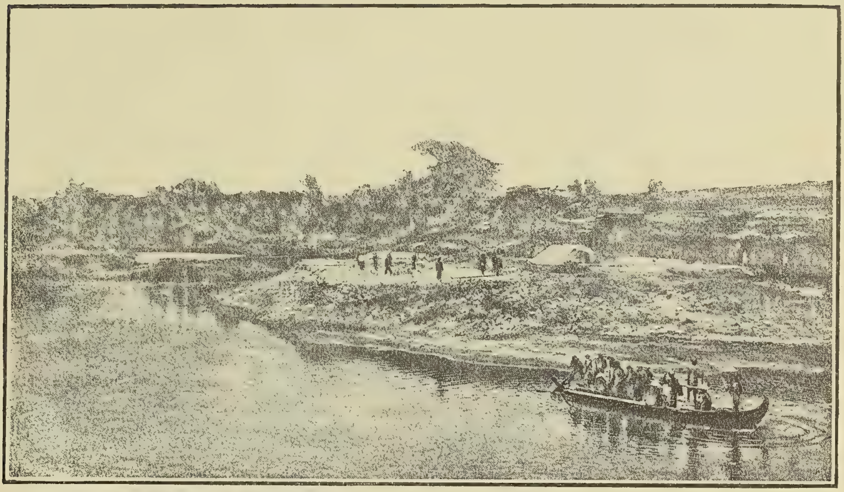


Fig. 1. Locality at which Pithecanthropus remains were discovered on the Bengawan River in Java. After L. Selenka and M. Blanckenhorn.

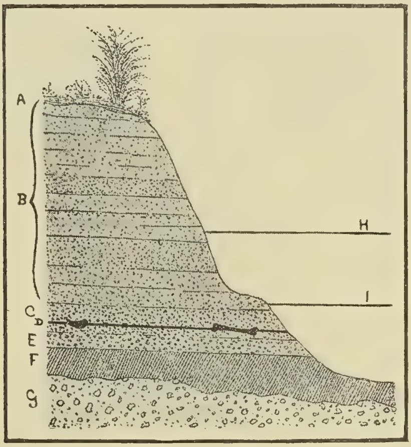


Fig. 2. Section of strata at the locality where the Pithecanthropus bones were discovered. *A*, area of growing plants; *B*, soft sandstone; *C*, lapilli stratum; *D*, level at which the skeletal remains were found; *E*, conglomerate; *F*, argillaceous layer; *G*, marine breccia; *H*, wet-season level of the river; *I*, dry-season level of the river. Adapted from E. Dubois.

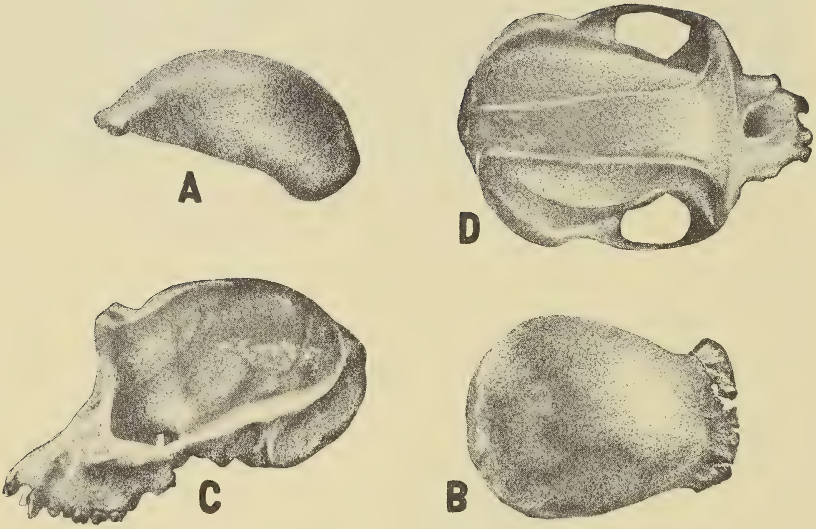


Fig. 3. *Pithecanthropus erectus*, Skull cap compared with skull of a modern chimpanzee. After E. Dubois. *A, Pithecanthropus* skull cap seen from the left side, × $\frac{1}{3}$; *B,* same specimen seen from above; *C,* chimpanzee skull from the left side, × $\frac{4}{9}$; *D,* skull seen from above.

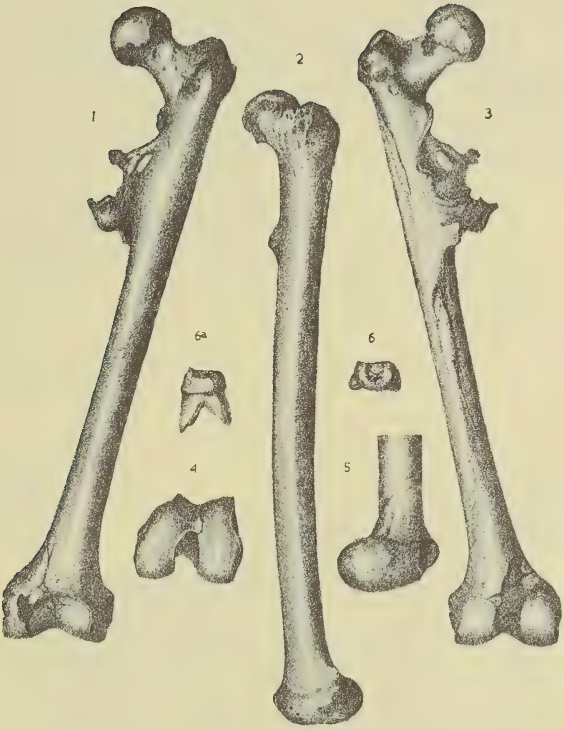


Fig. 6. Femur and tooth of Pithecanthropus. 1, Femur from front; 2, from side; 3, from behind; 4, from below; 5, lower end from median side; 6, Right third upper molar from below; 6*a*, from behind. Much reduced. After Dubois.

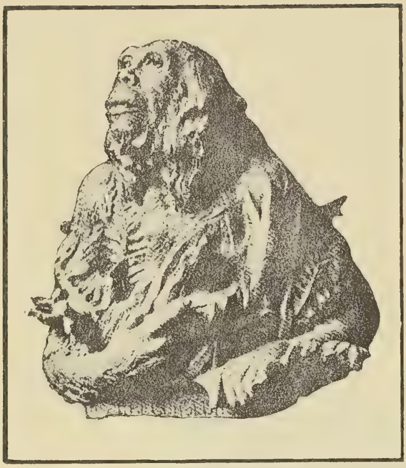


Fig. 8. Reconstruction of Pithecanthropus according to the Belgian artist Mascré, under the direction of Professor A. Rutot. After Osborn, "Old Stone Age," Charles Scribner's Sons.

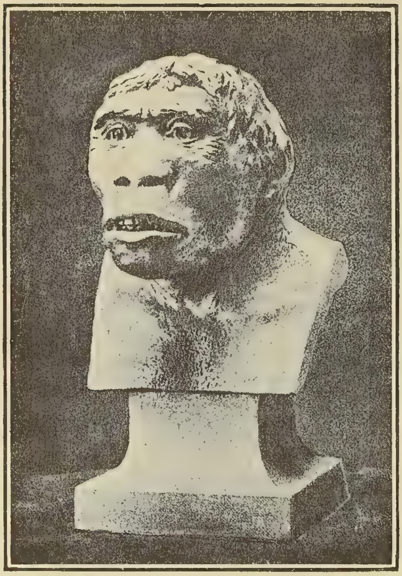


Fig. 9. Reconstruction of Pithecanthropus from the restoration modeled by J. H. McGregor. After Osborn, "Old Stone Age," Charles Scribner's Sons.

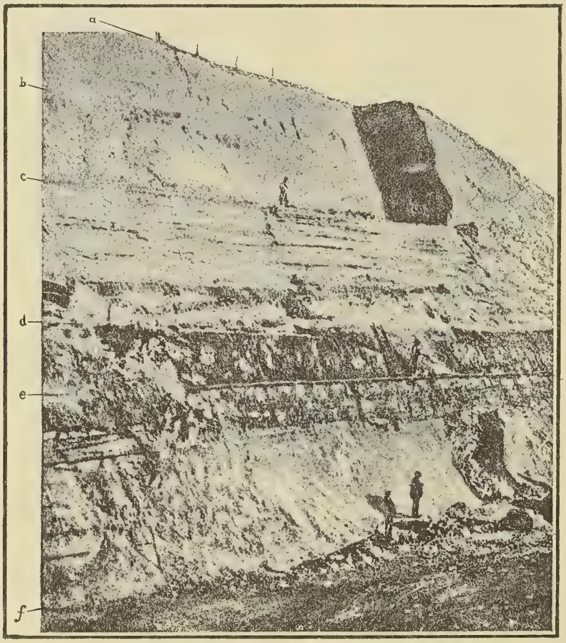


Fig. 10. Locality at which the Heidelberg jaw was found, at a depth of 79 feet below the surface. The white cross in the lower right hand corner of the picture indicates the occurrence of the jaw. After Schoetensack.

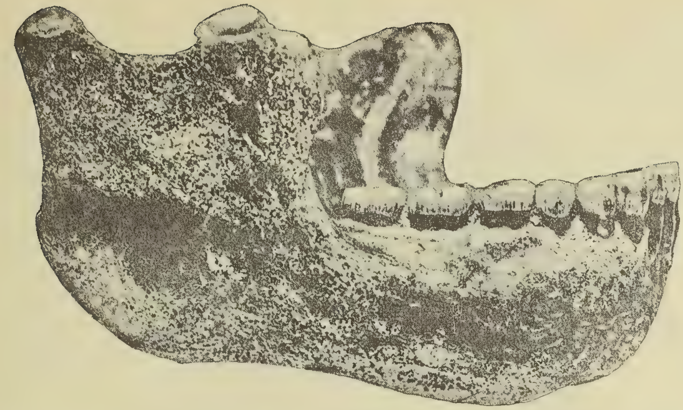


Fig. 11. Lateral view of the Heidelberg jaw, approximately two-thirds natural size. After Schoetensack.

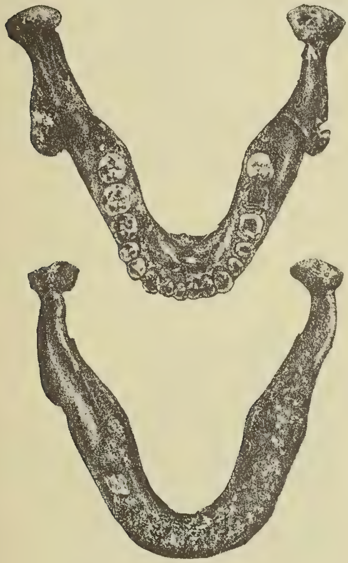


Fig. 12. Upper and lower views of Heidelberg jaw, slightly exceeding one-half natural size. After Schoetensack.

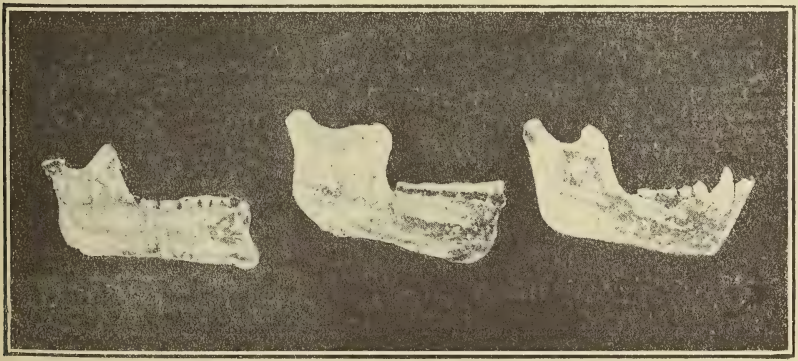


Fig. 13. Comparison of Heidelberg jaw in the middle of the picture, with a modern anthropoid to the right and an Eskimo to the left. After Osborn, "Old Stone Age," Charles Scribner's Sons.

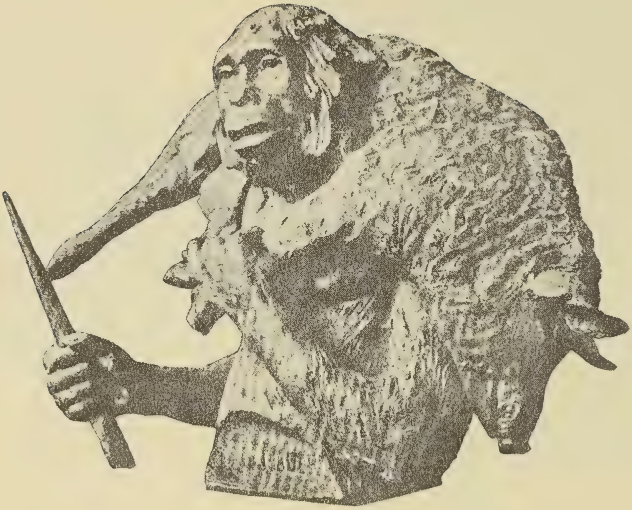


FIG. 15. Restoration of the Heidelberg Man by the Belgian artist Mascré under the direction of Professor A. Rutot. After Osborn, "Old Stone Age," Charles Scribner's Sons.

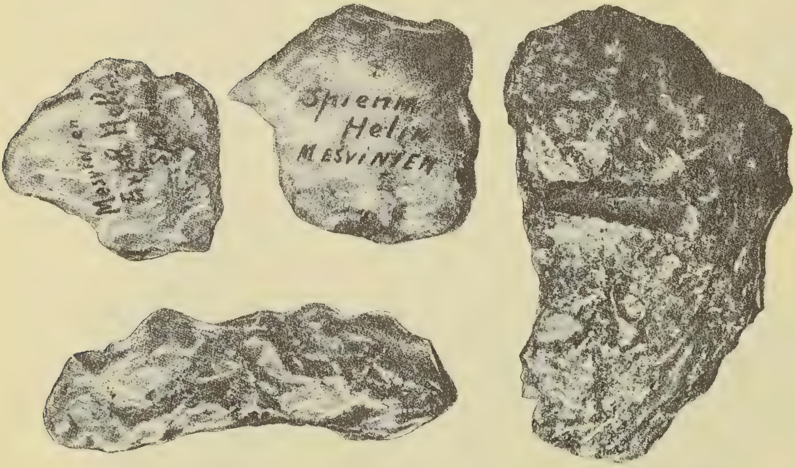


FIG. 17. Eoliths from Belgium. Approximately three-fifths natural size. After MacCurdy.

THE BEGINNINGS OF HUMAN HISTORY READ FROM THE GEOLOGICAL RECORD: THE EMERGENCE OF MAN

PART THREE

Pleistocene Stages in Human History Subsequent to the Time of Heidelberg Man

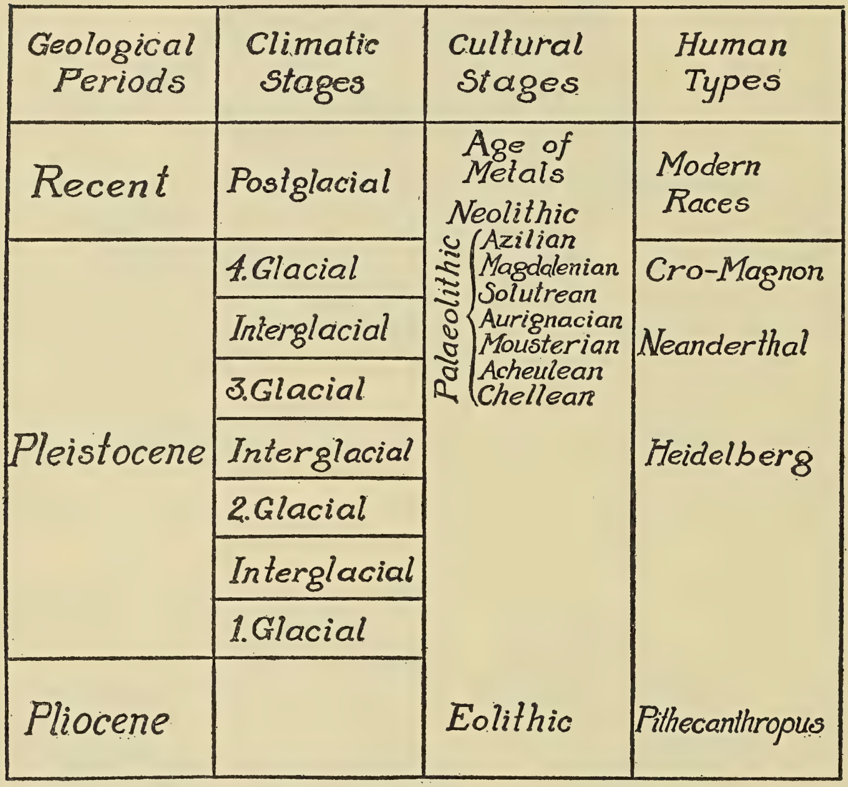
The earliest remains of man, known in the Pithecanthropus of Java and the Heidelberg type, are generally considered to represent stages of time not ranging far from the beginning of the Pleistocene period, or the geological division immediately preceding the present. It has been suggested that Pithecanthropus is of Pliocene age. The Heidelberg jaw was considered by Schoetensack to be possibly Pliocene, but is presumably not older than early or middle Pleistocene. With the exception of these two cases, the numerous occurrences of human remains found in deposits antedating the beginning of the present geological period are all generally considered to be of middle to late Pleistocene age.

Excepting a few widely scattered occurrences, ranging from Australia through Asia and Africa, the collections representing Pleistocene man have been secured from formations of western Europe, and discussion of the next stages in human history is as yet mainly concerned with early man in Europe. This record fortunately occurs in a division of the geological story to which extraordinarily close attention has been given by reason of the interesting fluctuations of climate marking this portion of time. Before proceeding with a discussion of the occurrences of human remains and the nature of the evolutionary sequence, it is desirable to sketch in a preliminary way an outline of the climatic and geographical history of this period, in which we find man passing through some of the most significant stages in the course of his evolution.

Delivered before the National Academy of Sciences in April 1918, as the third lecture of the sixth series on the William Ellery Hale Foundation. *Scientific Monthly*, vol. 10, no. 5, pp. 425–437, May 1920.

Fluctuations in Environment of Pleistocene Man in Europe

The story of glacial history in Europe corresponds closely with that of America, and is too well known to require more than the general statement that, during at least four stages in this epoch, climatic conditions were of such a nature that accumulation of snow and ice in enormous quantities was permitted at altitudes far below the present snow line. The extent to which the climate differed from that of the present time varied for the several glacial stages, but in the most extreme advance ice seems practically to have covered the northern half of Europe, extending over the British Isles and across the continent through Belgium, Germany and Russia. Ice also reached down from the Alps and other ranges to levels much below those at present touched by glaciers. Between



Geological Periods	Climatic Stages	Cultural Stages	Human Types
Recent	Postglacial	Age of Metals Neolithic	Modern Races
Pleistocene	4. Glacial	Palaeolithic Azilian Magdalenian Solutrean	Cro-Magnon
	Interglacial	Aurignacian Mousterian	Neanderthal
	3. Glacial	Acheulean Chellean	
	Interglacial		Heidelberg
	2. Glacial		
	Interglacial		
	1. Glacial		
Pliocene		Eolithic	Pithecanthropus

FIG. 1. Table illustrating relation of stages in human evolution to divisions of geological time.

the ice epochs, the climatic pendulum, swinging in the return beat, brought conditions in some cases more closely approaching those of the warm temperate regions than we find represented in the present climate of western Europe. It is important to note that it was in this time of frequent and radical changes in climatic conditions, and therefore of variation in the whole environment, including animal and plant life, that the present high level of human evolution was attained.

In the period of climatic changes of Pleistocene time the form of the land and distribution of water of the European region also varied much. Particularly in and near the second and third interglacial stages the British Isles and Iceland seem to have been connected with the mainland in the region of France and Belgium; the North Sea was dry, and land extended across from Scandinavia to England. During this period, the boundaries of the sea were in general moved farther out along the borders of the continent than at the present time. There seems also to have been land connection between Spain and northern Africa and between Africa and Italy.

During this period, we find not alone the climatic and geographical conditions subject to modification, but the whole scheme of animal and plant life shifted greatly from stage to stage. As would be expected, during the cold periods waves of migration swept across the continent of Europe from the north, and the Arctic animals extended their range to the lower lands; while during the stages of warm climate southern life reached north to England and middle Europe. Not only was the life shifting through migration of climatic zones, but great groups of species in many divisions of the animal and plant world disappeared, giving place to forms not known in previous time. These in turn became extinct and were largely replaced by new types before the beginning of the present geological day.

Deposits Containing Remains of Later Pleistocene Man in Europe

The geological record of Pleistocene time out of which we read our human history is obtained from a great variety of evidences, including the accumulation of deposits in seas, lakes, rivers, and upon the land. It is read also from physiographic records shown in the sculpturing of land forms by wind, water, and ice; and in the history of a continuously changing living world, both plant and animal. The sequence of deposits in which entombed organisms have been discovered is complicated and difficult to reach. It is moreover not the same record in all localities. Correlations or comparisons between widely separated regions are made with difficulty. It is, nevertheless, true that with the combined use of all known agencies, including the thermometer of climate in glacial history and the record of evolution shown in plants and animals, it has been possible through what amounts to international cooperation to work out a history with some degree of satisfaction.

The human remains of greatest significance in Europe have been found in deposits of two kinds, one consisting of stream accumulations of clay, sand, and gravel; the other the piling up of earth, gravel, sand, and stalagmite deposits in caves.

The relative age of stream deposits, and of their entombed remains, may be determined by the sequence of layers resting one upon another in a single area; or may be indicated by a succession of terrace deposits representing remnants of accumulated strata left stranded in the cutting of a valley. In general, we may not expect the best records of man to be found in formations made by streams. Although traces of skeletons are met occasionally, the destructive action of a stream is generally pronounced. Remains of implements, especially those of stone, being more resistant than skeletons, are better known in stream deposits.

The most important source of human relics of Pleistocene time is found in the numerous caves of limestone formations in western Europe. Caverns have always been places of abode for many groups of higher animals, furnishing as they do shelter from the weather and protection against enemies. Caves have been unusually significant in study of the life of early periods because they have served as concentration points for the remains not merely of their owners, but of the whole range of other animals supplying food from the surrounding country. Cave deposits are also of exceptional significance for the reason that in limestone regions, lime-burdened water dripping from the roof upon bones or other relics has often encased them with a calcareous or stalagmitic covering.

Man like other creatures seems early to have learned the advantage of cavern life. In the cave he also accumulated heaps of bones representing the animals upon which he preyed, and his bones like those of other animals were entombed in earth, clay, gravel, and

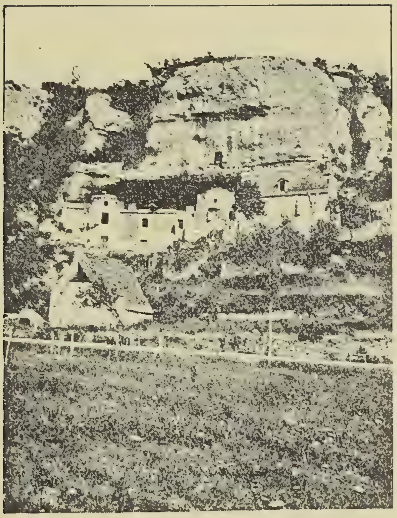


Fig. 2.

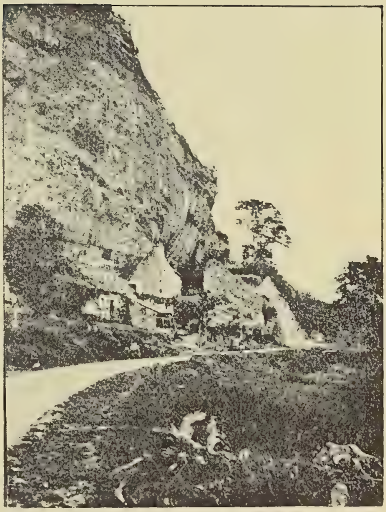


Fig. 3.

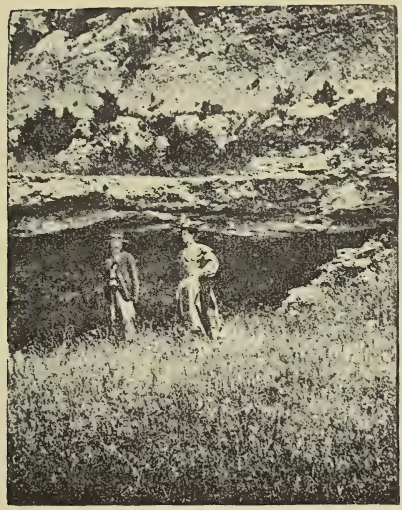


Fig. 4.

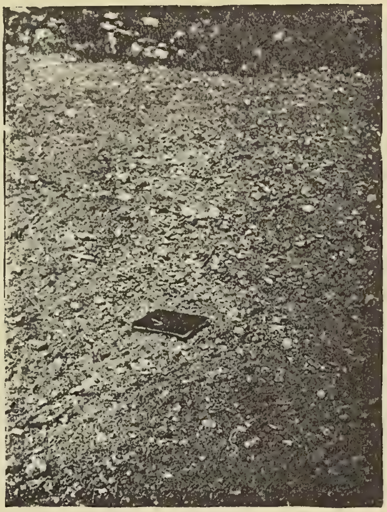


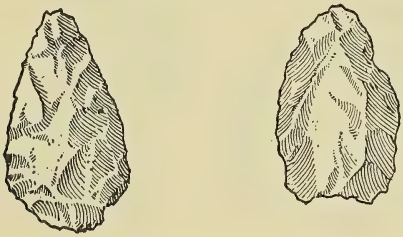
Fig. 5.

Figs. 2 to 5. Cave dwellings in the Vézère Valley, France. Fig. 2, Cave adapted for modern home. Fig. 3, Laugerie Haute, a modern dwelling on the site of cave deposits which contained remains of Cro-Magnon man. Fig. 4, Cave at Le Moustier, with deposits of Neanderthal stage. Fig. 5, Floor of Le Moustier covered with flaked flints.

stalagmite deposits in the floor of the room that was once his home. In our search for evidence concerning the history of man in the long period through which he worked his way up to domination of the natural world, no information has been found to exceed in interest the records held for ages in safe keeping in the caves. A story of the beginning history of our race comes to us from these sources filled with the thrill of adventure, and showing always the upward striving of becoming man.

River Drift Man

In the divisions of the geological record succeeding those from which we have obtained Pithecanthropus and the Heidelberg man there are several stages at which relics apparently representing human handwork have been found without accompanying skeletal evidence of man himself. Such remains are the flaked flints of Chellean and Acheulean types discovered especially in stream deposits of the Somme Valley in northern France and in the south of England. These objects are found in deposits evidently younger than those from which the earlier eoliths are obtained and show clear evidence of purposeful shaping. They are flaked in such manner as to leave no doubt concerning the influence of an intelligent creature like man in their forming. They were evidently produced by beings of the human type inhabiting Europe subsequent to the time of Heidelberg man and before the stage of the typical Neanderthal race.



Figs. 6 and 7. Flaked flints of the river drift stage. Fig. 6 to the left, fig. 7 to the right. Adapted from Reinach.

Neanderthal Man

Following the stage of Heidelberg man the earliest human relics of which we have evidence in skeletal characters are those representing the Neanderthal race. This type is now well known by skulls and other skeletal parts from numerous cave deposits of western Europe. With these remains there have been found also abundant traces of implements and of the contemporaneous animal life of this period. The materials available have made possible a very satisfactory interpretation of the physical characteristics, industry, mentality, and environment of the race.

The Neanderthal type has been best known by a now famous skeleton obtained in 1865 in a cave near Düsseldorf. Other specimens of similar type are the Gibraltar, Spy, Chapelle-aux-Saints, and Le Moustier remains, together giving full opportunity for interpretation of the characters of this remarkable race. All these skeletons represent beings distinctly human, and with moderately large brains, but possessing exceedingly low and generally depressed skulls with extraordinarily large ridge over the eyes.

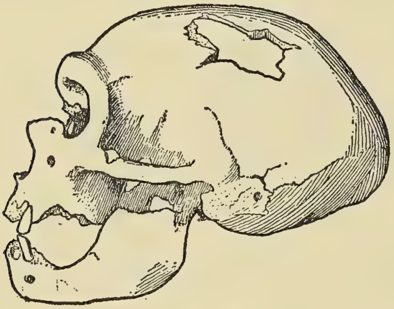


FIG. 8

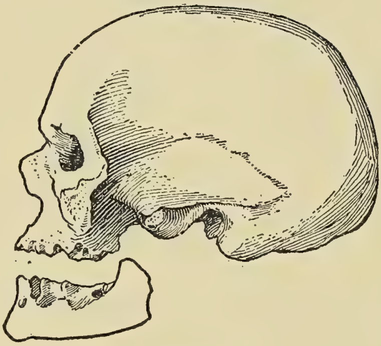


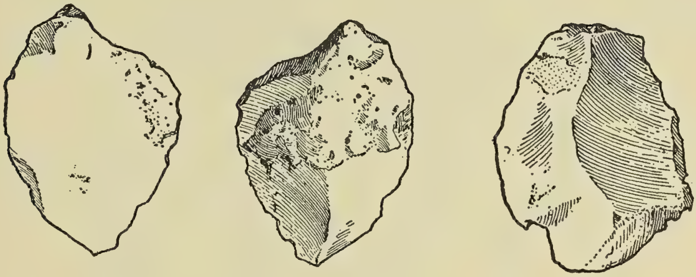
FIG. 9

FIG. 8. Skull of Neanderthal type from Chapelle-aux-Saints, France, × $\frac{1}{4}$. Adapted from Boule.

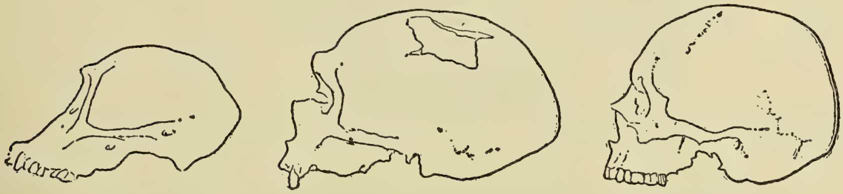
FIG. 9. Skull of Cro-Magnon man from Les Eyzies, France, × $\frac{1}{4}$.

Associated with the remains of Neanderthal man in the cave deposits at various localities there have been found great quantities of flaked flints which were evidently the characteristic implements utilized by this race. In the famous cavern at Le Moustier enormous numbers of flints are known, of which some are discarded implements and others are probably the by-products of implement manufacture. They all indicate a stage of development in which the flaking is sufficiently advanced to give a clean, sharp cutting edge undoubtedly used for a wide variety of purposes.

In the same deposits with the remains of Neanderthal man, and with the relics of his culture, there are found abundant skeletal parts of animals of the surrounding region which provided food and probably clothing. Other animal remains found in the caves may have been accumulated by carnivorous mammals occupying these shelters in intervals between periods of human habitation. From the evidence available we know that Neanderthal man was associated with the reindeer, woolly rhinoceros, woolly mammoth, horse, stag, giant deer, bison, cave bear, cave lion, and cave hyena. Many of these animals are now extinct and are characteristic of the Pleistocene Epoch.



Figs. 10 and 11. Flaked flints from floor of the cavern of Le Moustier, × ½. Fig. 10, middle and left-hand illustrations, are opposite views of the same flint.



Figs. 12, 13 and 14. Comparison of skull of Neanderthal man with a chimpanzee, to the left, and a modern man, to the right.

In many respects the Neanderthal type presents the most striking illustration of connection between the later stages of human evolution and the history of mammalian groups which in their development have trended toward man. The history of the Neanderthals lies well within a geological period distinctly separated from the present, the environment of this man was physically and biologically a world differing from the present, and the man himself differed markedly from any existing race. In very many ways the Neanderthals express that remoteness of time, difference of surroundings, distinct difference of physical characteristics, inferior level of industry, and limitation of mental development, which one might expect to find somewhere between Pithecanthropus and modern races if the existing human group represents progressive development out of a more ancient and less man-like stock.

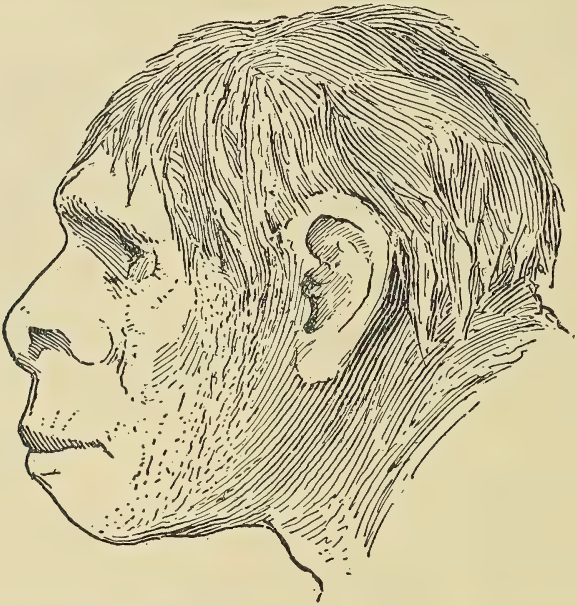


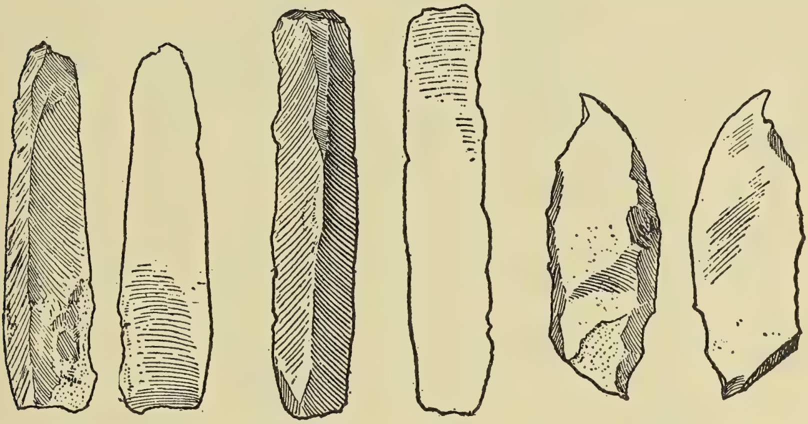
Fig. 15. Restoration of Neanderthal man. Drawn by Frieda Lueddemann, under the direction of the author.

Cro-Magnon Man

At numerous localities in western Europe we find abundant evidence that a type of human being differing widely from the typical Neanderthals occupied this region between the time of Neanderthal man and the present epoch. These remains are found in cave deposits, and like those of the Neanderthals are associated with abundant implements and with the remains of a wide variety of animals which as their contemporaries furnished food and clothing.

The history of this later type is known in several stages, of which one of the most important is that represented at the famous Station of La Madeleine, only a short distance from Le Moustier on the Vézère River in the French province of Dordogne. The skeletal remains of this race include individuals of large size, with skulls corresponding in outline to highly developed types of the present period. The brain case, like that of modern man, has a large content, and the form of the brain corresponds to that of vigorous mental types of the present day.

Judging from physical characters alone one could not avoid the conclusion that this Cro-Magnon type represents a form of man skilled in thinking and in the expression of thought through action. It is, therefore, not surprising to find associated with this race a wide range of beautifully formed implements shaped from stone and from the bones of animals hunted. The stone implements show an advance in the art of chipping or flaking developed in various forms, some delicately flaked, others giving long clean-cut lines and sharp edges. Implements of bone and antler are abundant and rival in their form and ornamentation the beautiful carvings of modern Eskimo. We find also on implements and on fragments of bone and antler extraordinary expressions of an artistic impulse represented in drawings of the contemporary animals and even of people. These illustrations show us the reindeer, the mammoth, and the bison, as living creatures fully known to Cro-



FIGS. 16, 17 AND 18. Typical Magdalenian flaked flints from the station of La Madeleine, France, × ½. Each figure represents two views of the same flint: fig. 16 to left; 17 middle; 18 to right.

Magnon man and pictured by him in characteristic attitudes of action. Even more remarkable if possible is the wonderful series of drawings and paintings left by this race on the walls of many caves, which were evidently not habitations but served some mysterious purpose not yet fully understood.

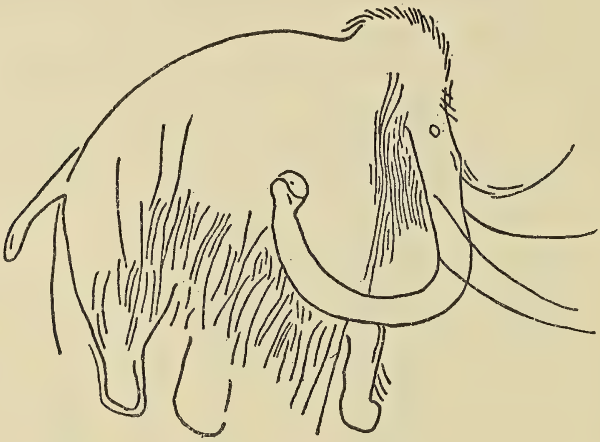


Fig. 19. Representation of the woolly elephant, drawn on the wall of the cave of Combarelles, Les Eyzies, France. Adapted from Capitan and Breuil.

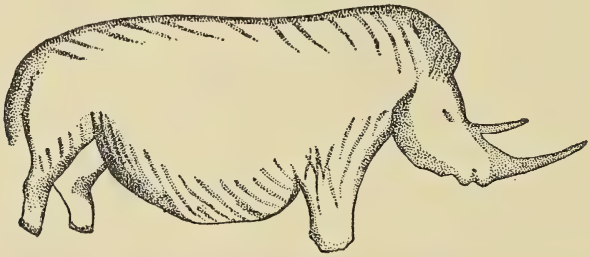


Fig. 20. Painting of the woolly rhinoceros, on the wall of the cave of Font-de-Gaume, Les Eyzies, France. Adapted from Capitan and Breuil.

The remains of animals associated with the Cro-Magnons include reindeer in abundance, horses, the woolly elephant, woolly rhinoceros, cave bear, lion, and many other creatures representing a fauna in considerable part extinct, and of which the surviving types are known largely from regions outside western Europe.

In physical development, and apparently in mentality, the Cro-Magnons approached closely the characters of modern man. This race represents in western Europe the beginnings of modern life taking its origin in ancient times. The Neanderthals go far in physical characters, in mentality, and in environmental setting to bridge the gap between present-day man and the earliest humans. The Cro-Magnons suggest to us that the modern cast of physical development is rooted deeply in the past, and that the relatively high intelligence of the human race today is based upon physical change and complication which have required for their accomplishment a measure of time approximately commensurate with the advance in mental ability.

SIGNIFICANCE OF DATA BEARING UPON THE PROBLEM OF HUMAN ORIGIN

Passing in review the stages in evolution of man, it is desirable to note once more the evidence of geological succession of the four human types already discussed, and with this to state that all four were present on the earth before the beginning of the present period. The proof of their antiquity seems especially striking when we consider that between the time of appearance of the third or Neanderthal type and the present day events of great geological and biological significance profoundly changed the face of nature, and that after the Neanderthals had become established in Europe a period of fifty thousand to two hundred thousand years probably elapsed before the modern races became dominant.

It should be noted again that remains of the later stages, including Neanderthal, although apparently absent from the New World, seem widely distributed over the Old World. The first two stages, represented by Pithecanthropus and Heidelberg man, are known by single occurrences, and the one generally assumed to be the earlier is situated in a region known to be an area of evolution of the anthropoid group.

We have also seen that the series shows us, in passing backward through it, a reduction in brain capacity, increase in the prominence of the face, and general taking on of anthropoid characters, until the earliest form is recognized as unquestionably of all human types the one standing nearest to the apes, and yet apparently distinguished from anthropoids by its specialized human limbs.

While the evidence is incomplete, the record as it stands agrees even to extraordinary detail with the expectation which one might have of early human history based upon the view that man, while a derivative of the anthropoid group, has become widely separated from all simian types, and presumably required long ages in which to reach his present stage of differentiation away from the primitive stock.

The earliest occurrences of human remains are at the geographical point where we would expect to find them. The earliest types represent approximately the stages of evolution that the paleontologist would anticipate discovering in the strata from which they have been recovered. The later history shows a gradual modification at a rate corresponding in general to that seen in history of other groups of mammals. We note also that the family seems to spread itself gradually over the world, and as nearly as we can determine, with this wider distribution there begins the differentiation into distinct types or species characteristic of geographical provinces.

In a word, human history, so far as the development of physical or biological man is concerned, indicates that our origin is comparable to that of other organic groups, and that we are apparently an outgrowth from the mammal world subject to the same laws of evolution and differentiation as are expressed in myriads of other organic types. The existing races of man represent the morphological and geographical expression of this evolutionary history. Their characteristics are clearly the result of hundreds of thousands of years of differentiation. The stamp that is put upon each type is the product of extraordinarily complicated influences in which inheritance and environment are essential elements. It is not a fleeting impression, but has significance comparable to that definiteness in organic type which leads us to expect the rose to beget roses, and lions to be the offspring of lions.

As was noted in the introduction to the first lecture, students of biological aspects of the human problem have recently called particular attention to the importance of race as weighing definitely in consideration of many world problems, along with the factors based upon differentiation of peoples according to linguistic stocks, ethnologic relationships, and social organization. This is not interpreted to mean that great significance does not attach to the group influence in peoples organized according to ethnologic characters, or by reason of the effect of language, or through many other causes. It does mean that factors of fundamental significance brought out in our long history, and represented now in race, have perhaps received less consideration than is their due. It means not only that a clear view of the human situation must present a picture showing the common characters represented in practically all human types and individuals, but that with these we must see also the length and breadth, the height and depth of human differences. Unless this view is taken we shall fall short of the interpretation of humanity needed in order to give to every group, as well as to every individual, that full freedom to develop *its own peculiar talent*, and to grow into the fullest usefulness which we assume to be the natural right of all.

And finally, the whole trend of history within the chapter just read from ancient records exhibits without question a definite progressive movement of the human type. This is expressed in physical capacity for greater breadth of comprehension, and in wider range of activity and occupation given by coordination of the brain and hand as also of the brain and tongue. Man of the present day may read his story back to that early stage in which he first sees himself distinguished from the beast. He sees the beast become a man-like beast and then a man. Perhaps to you the student of this ancient life has seemed to look upon a passing scene which might well have been left unknown—and yet to those who read what he who runs may see, the present world is brighter for the view—the future built upon the upward striving of the past must see the best there is in life at length prevail.

PRESENT STATUS OF INVESTIGATIONS CONCERNING ANTIQUITY OF MAN IN CALIFORNIA

The fact that archeologists and historians have been interested in the problem of the antiquity of man in California for the past 60 years is due in a considerable measure to the peculiarity of the problem in that region. The California area offers exceptional opportunity for a great variety of studies in archeology and anthropology, and especially for those dependent upon our knowledge of geological processes of the present and of the period immediately preceding. The fact that the coast region of California seems to have been in almost continuous movement throughout the later geological periods means that there has been continuous erosion accompanied by continuous deposition, giving us at the same time a record of the processes of erosion and deposition and of the life of the region in this period.

It has been realized from the beginning of our studies on the Pacific Coast that satisfactory conclusions regarding the antiquity of man in California can not be reached within any narrow time limits, and that no single mode of attack may be considered sufficient in itself. At the initiation of the studies conducted at the University of California four lines of investigation were laid down: (1) Tracing man back in time through an examination of the great shell mounds of the coast region, the most critical study being given to the lowest or earliest deposits. In this work opportunity was offered for going from the known culture of the uppermost layers of the mounds back to a period in which conditions may have been quite different from those governing the life of the Indians of the last centuries. (2) The thorough investigation of all available cave deposits, whether Recent or Pleistocene, with particular reference to possible human occupation. (3) A careful study of those Pleistocene and Recent land, stream, lake and marine formations in which the occurrence of human remains or

Paper presented before the National Academy of Sciences, Washington, April 29, 1924.
Science, n. s., vol. 60, no. 1540, pp. 1–2, July 4, 1924.

relics appears possible. This comprised a study of many Pleistocene formations and the collection in them of all obtainable fossil remains. (4) A careful review of all evidence relating to the reputed occurrence of implements or human remains in the older gold-bearing gravels or other ancient deposits of a similar nature in California.

After practically 25 years' research on the antiquity of man in California from the point of view of the archeologist, anthropologist, paleontologist and geologist, it is clear that the problem is not only extraordinarily interesting but is exceedingly complicated. There are many evidences in caves, in alluvial and stream deposits, in the shell mounds and in asphalt deposits, indicating the occurrence of man on the Pacific Coast for a period which must in all probability be measured in terms of many thousands of years. Up to the present time all the human remains discovered are of what have been recognized as modern types. So far as has been determined they do not differ materially in their characteristics from the various races included within the group of the American Indians of to-day. The implements and other evidences of man's handiwork are also in general of modern appearance and different from the ancient types known from the Pleistocene deposits of Europe.

Up to the present time no definite evidence has been secured in California of the occurrence of human remains in a geological formation older than the present or Recent period. Although there are occurrences which have suggested the possibility of man's existence in the Pleistocene or the period immediately preceding the present, most careful investigation has not up to the present time given us definite evidence indicating that either human remains or implements produced through the work of man have been recovered from deposits antedating the present geological period.

Though the geological evidence before us does not give for the Pacific Coast of America any clear proof of man's presence in the Pleistocene, during which he is known to have been distributed widely over the Old World, this must not be interpreted to mean that the human race has not been present in that region for many thousands of years. A time measured in thousands or perhaps tens of thousands of years would naturally be required for the development of such divergence as we know among the physical types of

America, and would also seem to be required for origin of the differences in culture and in language so abundantly represented among the aboriginal peoples of the western hemisphere. The geological evidences of occurrence of man in California permit our considering the possibility of his presence there for at least as long a time as seems required by the evidence of his physical and cultural differentiation on this continent.

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PANAMA AND THE PROBLEM OF HUMAN MIGRATION

One of the most important advances in modern interpretation of history has come through recognition of the vast length of time represented and the almost infinite complication of events. We now appreciate also the significance of changes in human environment, whether arising from modification of our surroundings at given places, or from changes due to migration across varying types of environment.

Although the period covered by human history is brief compared to that represented in the great stretch of geological time, we now recognize the story of man as beginning at a date so remote that many tens of thousands of years must be reckoned in study of the historical sequence. While changes in the physical and biological environment of man within known human history are comparatively small when measured against those seen in the whole stretch of geological eras, there is an important element of variation recognized within the period since man appeared.

It is also noted in modern interpretation of historical sequence that frequent movements of human types up and down over the greater land areas of the earth have brought about a situation so complicated that it becomes impossible to obtain a clear view of the historical development of any race or any people without following its story over wide reaches of the earth's surface.

Relation of the problem of human migration to conditions obtaining at the Isthmus of Panama are of exceptional interest by reason of the fact that the area of Panama lies in the path of some of the most interesting migrations of life in America within comparatively late geological time. Although human history is not necessarily involved in the whole of this story of migrations, the principles which govern interpretation of the human story are so closely similar to those involved in the migration of other types of

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Presented for inclusion in the program of the Pan American Congress, Panama, June 1926. *Bulletin of the Pan American Union*, vol. 60, no. 8, pp. 787–789, August 1926.

life, that we must to a considerable extent consider the two by the same methods.

One of the outstanding features in the history of relationship between North and South America is the evidence of complete separation of these continents for a long period preceding late geological time. During this period of separation a wide difference in types of life was developed, especially in the case of the higher animals. At a time approximately two geological periods preceding the present epoch, North and South America had almost completely different forms of higher animal life. Suddenly in late geological time North American forms appeared in South America and South American types appeared in North America. Intermingling of faunas continued for two geological periods, with strengthening of North American representation in South America and concurrent weakening of South American representation in North America.

During the period of separation of South America from North America, the life of the southern region developed a peculiar type due in considerable measure to its isolation. When the continents became connected in late geological time, the results of intermigration gave us an almost completely new type of population for the southern continent. The present fauna representing higher types of life in South America is largely of North American origin. Relics of the ancient fauna appear in the armadillo, sloth, monkey, and other animals.

During the period in which South America and North America were separated, the North American region was connected with the Asiatic region. The animal life of this northern region was the result of many migrations over this great northern land mass including North America, Asia, and Europe.

Our knowledge of human history in America is as yet represented only by interrupted chapters or fragments of the story. With continuing intensive historical and archaeological investigations over the two Americas we shall ultimately obtain a large part of the information necessary to construct a complete history. It is natural that at the present time we find numerous opinions as to the origin of American peoples, regarding entrance of human groups into these continents, and concerning extent and character of fluctuation in migrations. The concensus of present opinion would probably favor derivation of all American human types from Asia and their introduction to America by migrations passing through Alaska. These migration routes have evidently spread in many directions through North America. Some have converged at the southern end of the continent. From these southern lines the routes of exploration and travel into South America have passed over, or close to, the Isthmus of Panama.

There may have been short cuts or roundabout routes. Many assume direct entrance of immigrants from Asia by routes across the ocean resulting in landings at widely separated points along the Pacific coast. Perhaps the original migrations were all by way of Alaska and later influences came to exert themselves by landings at various points on the Pacific margins of the continents.

By whatever theory the history of human occupation of America can be interpreted, the region of Panama and the areas immediately to the north and south must inevitably represent one of the most interesting portions of the Americas for study of routes of migration and influence of environment upon the people. There can be no doubt that the region of Middle America will be one of the centers of attraction for future study of the general ethnological and anthropological story of America. There is every reason why this region should be made the subject of most intensive geological, biological, and anthropological study with expectation of results of great importance in their bearing upon fundamental questions of American history.

THE PRACTICAL SIGNIFICANCE OF STUDIES IN EARLY HUMAN HISTORY

Before referring to the title of my talk, may I say that it is a great privilege to me to be with you this evening to celebrate the accomplishments of the Anthropological Society in the past half-century. I lived long enough away from Washington, during the period when I was at least actively thinking, to realize in some measure the influence of this organization. It does not appear in the books, perhaps, as often as other agencies which show great accomplishments and carry through impressive expeditions, but I have always a feeling that, in the background, the Anthropological Society has been through these many decades a place for the meeting of minds, where ideas are threshed out. What I have in mind more particularly relates to the influence of this organization and related bodies upon the development of the science of man in America.

Just because Washington has not been mainly a university city, there has perhaps been a feeling that the educational influence of scientific work in Washington has been less than that of many other cities. New Haven, with its great university; Cambridge, with its Harvard; Chicago, in the later days, with its unquestionably outstanding institution, we all recognize as having enormous influence upon the thought of the country. But in the same measure it has seemed to me that the great institutions here, including the Anthropological Society, have had their tremendous influence, not so much upon the student at the time he is studying, as upon the instructor who leads him, moulding the ideas which ultimately come to be imbedded in the structure of education.

I believe in education in all its phases; they are all necessary, all important. I am only making the point that the kind of thing done through a meeting of minds here is something that must not be forgotten.

Address at the semi-centennial celebration of the Anthropological Society of Washington, February 19, 1929. *American Anthropologist*, ser. 2, vol. 32, no. 1, pp. 196–198, January–March 1930.

This is such a great group of scientific men that, when I used to come across the continent twice a year to visit Washington, I always wondered why I never could see all the people I planned to visit in Washington. I finally discovered that it was because there were so many leading people there that in the time I had available in my vacation I could not find opportunity to see them all.

As I stand off and look at the scheme of the sciences, I am more and more impressed with the tremendous significance of the field which you represent, that is, the broader study and interpretation of man. Today we are in what many would call a period of mechanism, an age of physics and chemistry. Perhaps this is true, and it may be that in other decades we shall look back at this particular time as one of high development and relatively great importance. The subjects involved in physics are enormously important, more significant than we ever supposed them to be, but I do not for one moment think that they are more important than anthropology.

Biology is built out of the atoms and the molecules. It is a more complicated thing. Physics is relatively simple. Superimposed upon biology comes a great development arising out of the nervous system. We are then at the beginning of mentality or intelligence. Whatever road we follow leads us ultimately to a consideration of the problems that are basic in human studies, that is, human conduct and what it means. This is a thing so complicated, so different, so nearly infinite in all its ramifications, that it is well to take a prayerful attitude before beginning work and expressing an opinion regarding it. We are just now beginning to see that anthropology, or even biology, may be handled scientifically, with the expectation of results. We are just beginning to see that there are laws or modes of procedure which may be organized and tabulated. We hope that ultimately they will lead us to some interpretation of the meaning of human conduct, and human thought, and human interest and aspiration. There will be no end to this study. From age to age we will learn a little more, and a little more. This will not merely mean that we shall be able to put it all down in books or formulae. It will mean that men will live a more comfortable and more effective and more interesting life, a life of greater accomplishment, and a life of greater enjoyment.

I have found only one fault with anthropologists in general. Sometimes I am afraid they do not take their responsibilities seriously enough. Perhaps it is wise not to take them too seriously until we reach the point at which we are able to accomplish something. There is just as great a danger in trying to turn the world upside down because we have discovered its importance as there is in not recognizing that the subject may ultimately become important.

I said I was a little bit disappointed because anthropologists do not recognize their responsibility. On the other hand, I am with you when I realize that you are moving slowly and trying to make the way safe. You will not save the world in one week or in one year, but you are paving the way, which is to be made wider and broader for the future generations.

You have a great mission. There is no greater work than that which you have of attempting to understand man. It is a thing that may well challenge interest.

What I have to say regarding the study of early human history may be stated more briefly than what I have already presented. At this period we are beset by people who think everything is directed toward "the demnition bow-wows." Man is thought to be creating a great machine, which he will not be able to control. Many are writing books because they think they have a message—sometimes they have, sometimes not, and they believe their message is to show that the world is running away from us, the machine is too powerful and man is sliding rapidly to his own destruction. I have no sympathy with that view. We are creating a machine. Probably we shall always be doing this. When, as a geologist, a paleontologist, an anthropologist, I look back over what we see of the history of the world I find there have always been machines of some sort, in the clutches of which life seemed to be set, but nearly always life seems in some way to have developed just a little more rapidly than the physical forces around it. Out of the muck and slime, out of the shock of earthquakes and the smoke of the volcanoes, man has emerged increasingly intelligent through the ages.

We may know something about what is just behind us, and a little less of what is just ahead of us. Out of the past I see something that has indicated the development of life to higher and higher levels. We do not know all about it, but I can see that much has taken place. I can see marching down through time the something that looks like man of the present day. I do not think we have all the connecting links, nor have we any phase of history complete.

It seems to me that it means that this thing that we call life, and the kind of being that we call man, each in its place has had opportunity to go on building and building. I have no sympathy with those who feel that we are just building something to overshadow us and then die in it. In every age, through all time, the organism of human life has developed faster than the environment that has been built about itself. I cannot conceive of any scheme which would bring man to this particular stage and then fail to leave him the right to improve himself so as to keep ahead of the thing which he constructs.

A few weeks ago I suddenly discovered that the motto of the Carnegie Institution of Washington contains the words "research, discovery, investigation, and the application of knowledge, not just to the betterment of mankind, but to the improvement of mankind." I wondered whether the person who wrote it had in mind that a part of our business in this world is to see not only that we build around us, but that man himself has an opportunity for improvement.

There is a word that is used commonly these days that is spelled "eugenics." It is in a general way the idea that we have the right to be well-born. I conceive of it also as meaning that people have the right to be better and better born through the ages. Not less important than that which has come to all generations preceding us, the subject of eugenics must be considered from many points of view. We know something of the new Institute for Human Relations which is now being established at Yale University, a very great thing, the interrelation of studies that have to do with anthropoids, with the intimate structure and physiology of man, the relation of it all to laws of human conduct. It will not be possible to solve all the problems at Yale, nor do they expect to. They will not solve them all with that one institute, or in this century, but we are making a beginning, one of many beginnings of a study that has as its object this greater thing—the understanding of our capacity and the means of improvement of mankind in future generations.

As to human history, from my point of view, the most illuminating, the most comforting, the most stimulating idea that we secure from science comes out of that part of history which we find in the study of early man, the idea that man has tended to keep moving, to keep improving, to keep on developing his understanding of other creatures about him, and of himself.

I feel that eugenics in the strictly scientific sense is a portion of anthropology, and in reality is one of the great coming subjects, one which will help us to make man so much better that nothing he builds will ever overpower him. But the great stimulus, and the great hope to the eugenicists, it seems to me, comes from the broad, clear vision of what the anthropologists, together with the historians, have discovered in this picture of development of man as we see him coming up through the vast aeons of his early history.

CRITICAL ELEMENTS IN STUDY OF EARLY MAN IN SOUTHWESTERN UNITED STATES

Critical elements in study of early man in southwestern United States: John C. Merriam. The most ancient occurrences of human remains in southwestern United States present a problem of exceptional interest by reason of the fact that the record of associated life and the details of geological history are relatively more abundant than in many of the regions of the United States where effort has been made to work out the early history of man on this continent. Frequent crustal movements in the region of the Southwest have produced extensive and deep erosion, together with wide-spread and thick accumulation of deposits. In some localities the volume of material thus accumulated, the number of strata represented in the record and the multiplicity of geological incidents arranged in sequence present a background against which projection of the record of life becomes unusually interesting. The extent to which changes in the fauna and migration of life among regions of the Southwest shows relatively large number of changes is yet to be determined by working out of details in both geological and paleontological history. There is some reason for belief that the paleontological history will show a contribution comparable to that of the geological story of the Southwest. With the background of geological and paleontological data presented it becomes of exceptional importance to make intensive study of all remains of man found in the West and especially in the southwestern area of the United States. In connection with previous studies heavy emphasis has been placed on determination whether strata in which human remains have been found are of Pleistocene or Recent epochs. For the moment it is important to learn what the historical sequence is regardless of whether the remains happen to be Pleistocene, Late Pleistocene or Recent. Once the paleontological or archeological sequences are established it will be easier to determine the correlation with stages of the Recent or Pleistocene which have been accepted as standards.

Abstract of paper presented at the autumn meeting of the National Academy of Sciences, Pasadena, September 18–23, 1930. *Science*, vol. 72, no. 1868, p. 405, October 17, 1930.

A REVIEW OF EVIDENCE RELATING TO THE STATUS OF THE PROBLEM OF ANTIQUITY OF MAN IN FLORIDA

INVESTIGATIONS by Sellards, Gidley and others have presented evidence suggesting the association of human remains with those of a Pleistocene fauna in the Florida coast region. The area in which this interesting occurrence was noted has been studied carefully by many anthropologists, archeologists, geologists and paleontologists, with the result that sharply differing opinions have developed regarding the meaning of these materials.

The classic localities for these finds of ancient human remains at Vero and Melbourne in Florida were examined by the writer in 1932. At that time it was possible to visit the exact points at which some of the most important specimens had been secured, under guidance of Frank Ayers, who had been associated with the original discoveries. These localities were visited again in 1935 in company with Edgar B. Howard, of the University of Pennsylvania Museum.

In making a study of the localities at which ancient human remains were found in Florida it was the purpose of the writer to determine, if possible, whether the association of extinct faunas and human remains suggested an association or sequence comparable to what has been found in southwestern United States. On the visit in 1932 and again in 1935 the impression obtained was that, at the localities visited, the occurrence of remains of certain extinct animals considered to represent a Pleistocene fauna suggests the type of association known in the Southwest, where human relics appear with a fauna now, at least in large part, extinct. Whether this means that man was present in Florida in Pleistocene time or whether animals now extinct lived in that region in what may be called early Recent time, will be determined by more intensive studies of the stratigraphy, physiography and paleontology of this region than have yet been made.

CARNEGIE INSTITUTION
WASHINGTON, D. C.

Abstract. *Science*, vol. 82, no. 2118, p. 103, August 2, 1935.

PRESENT STATUS OF KNOWLEDGE RELATING TO ANTIQUITY OF MAN IN AMERICA

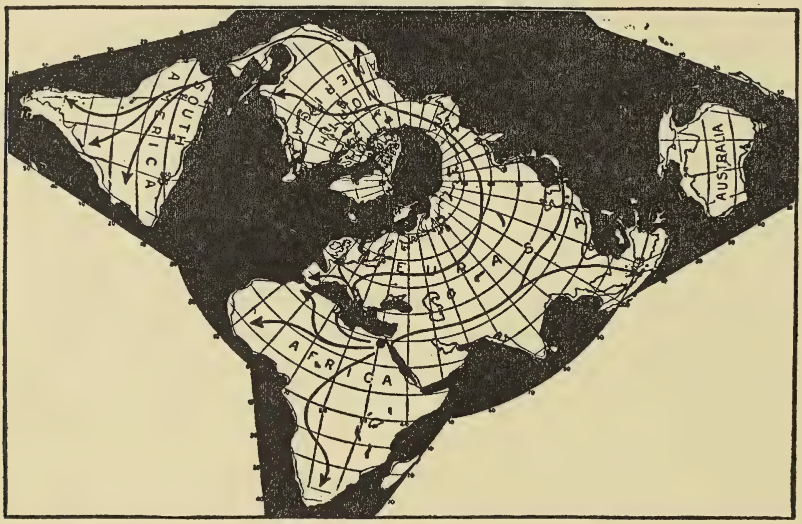
From the point of view of a geological congress, discussion of antiquity of man in America may be assumed to focus upon questions involving possibility of human remains or artifacts occurring in deposits antedating the Recent epoch. The geologist concerns himself with data which have to do with existence of the race within a time recognized as geologic history. The approach of the geologist involves use of criteria by which geologic age is determined and concerns factors that have to do with formation of the stratigraphic record, crustal movements, physiographic changes, and climatic variation.

Assumption that man is a product of evolution out of less advanced animals, such as the anthropoids, gives to study of antiquity of man in America a viewpoint somewhat different from that in the Old World. Known representatives of the primate group in America have seemed so far removed from immediate ancestors of man that there has been little disposition to consider actual origin of the human race on the American continent.

Derivation of man from primate types of South America has been discussed, but consensus of opinion indicates that it is Old World forms, and not those of South America, from which the human group has developed. Although in the Old World one considers both origin and development of the human race, in America the problem concerns entrance by migration from the other side of the world. While general opinion leads us to look toward Asia, Europe, or Africa as place of origin of the race, this does not mean that early representatives may not have been present in America, and we are not justified in eliminating the possibility that a con-

Preprint of *Report of XVI International Geological Congress* (Washington, 1933), pp. 1–5, July 1934, with list of references compiled by Frank H. H. Roberts, Jr., pp. 6–11; under the title "Early Man in America" with slight revisions, *Carnegie Institution of Washington News Service Bulletin*, vol. 3, no. 23, pp. 185–190, August 11, 1935; *Report of XVI International Geological Congress*, vol. 2, pp. 1313–1317, 1936, with list of references as above, pp. 1328–1323. Illustrations reproduced here from *Carnegie Institution of Washington News Service Bulletin.*

siderable part of the history of man as a tool-making animal may have a record in America. As unfolding of the geologic story proceeds, it is generally accepted that abundant time has been available for many migrations and many changes. It is not outside the limits of reason to assume that the human race may have penetrated the American continent on numerous occasions before it became sufficiently entrenched finally to develop such numbers as made possible adequate record of its presence and the stages of its evolution.



Theoretical migration routes of the mastodont family from their center in Africa to all the continents excepting Australia. The cradle of the elephant family is still unknown.

Especially prominent in consideration of man's antiquity in America has been the question whether his entrance preceded or followed the close of the last stages of continental glaciation. There has also been discussion concerning the possibility of human record in stages as far back as middle Pleistocene. In the main, investigation has ranged around consideration of existence of human beings in North America during the last stages of Pleistocene time.

Study of early man in America has naturally been approached, as in other regions, through all phases of investigation which may in any manner touch human history. Although overlapping widely in many directions, there have naturally been three groups with their several points of view—the archeologists, the paleontologists, and the geologists.

Although archeological investigation involves a vast number of elements scattered over practically the whole field of science, it is in studies of this group that we find expressed specifically the problem of human culture as illustrated in evidences of activity directed by intelligence.

The paleontologist, concerned broadly with the history of life, may not avoid recognition of influence by mind in human history, but fundamentally his province covers the biological story. Trained to recognize organic modifications or changes expressed in space and time, the student in this field considers the problem of early man in a manner corresponding to that in which he follows the history of the horse or the dinosaur. Whatever other opinions may be voiced regarding significance of the physical changes in man through history, it must always be borne in mind that the paleontologist is the expert trained to recognize the meaning of such details as relate to the problem of evolution.

The geologist is the expert on problems touching formation of the record, significance of changes concerning distribution of land and water, modification of climates, influence of crustal movement, and all of the major factors that have to do with movement of events in earth history and the elements in environment of life through the ages. Specifically, it is the geologist, concerned with problems of stratigraphy, glaciology, physiography, from whom assent must be had before we are in position to date the deposits in which human remains are found with anything like assurance.

Although the several elements involved in examination of the story have been defined separately, it is important also to call attention to the fact that while we require the opinion of specialists in each field, the next stages of advance are to be made by effective integration of all the parts of this story in such manner as to obtain largest value from each phase of the investigation. One of the most significant aspects of human history concerns the idea that the story as seen by the archeologist interlocks with that as seen by the geologist and the paleontologist.

If any specific influence be exerted by this International Geological Congress on problems concerning early man, it is important that there be recognition of the idea that the human story cannot be understood completely on the basis of consideration of any one locality or region; nor can it be worked out adequately unless there be coordination of effort representing all the modes of approach thus far used in study of the problem. The great length of time involved, the wide variety of changes in physical human types, the infinite variations in cultural development, and finally the tendency of man to be led by his curiosity into all possible situations, either as to condition or as to region, mean that there is need for securing not only all possible data but every available means of interpretation through united effort of all the groups of scientists concerned with study of this problem.

During early stages in development of our knowledge of the history of man in America, evidence available seemed in some ways contradictory, and, as in many other fields of research, contrast of opinions tended to develop rather widely separated groups. It was therefore necessary to wait for additional evidence through which the apparently incompatible views could be brought into intelligible relation to each other. One group tended to accept the presence of man and highly developed evidences of his work in periods reaching as far back as the Pliocene. The other group has been inclined to doubt evidences of occurrence earlier than the Recent period.

The Calaveras skull perhaps represents an exaggerated example of the first point of view. The evidence which it afforded seemed to require presence of man on the west side of the continent in Pliocene time. In many years' study of this particular problem the writer was interested to find a considerable number of apparently authentic occurrences of human remains in the older gold-bearing gravels of California. The data had been furnished by men of the highest reputation, including no less a person than the geologist Clarence King. Leading citizens with unquestioned reputation as to veracity gave their personal affidavits regarding location of these finds in formations known to be of great age. It has been the privilege of the writer and those associated with him to follow many of these stories through a long and difficult route which has led to explanations not easily attained by earlier investigators. The formation from which the Calaveras skull was supposed to have been taken we now believe to be much older than the period to which it was assigned by Whitney. The skull, which was thought by some to have been taken from an Indian burying ground and placed in a mine as a joke, seems not to have come from a burying ground but from a cave deposit, perhaps of considerable age, in the region near Angels Camp. Numerous artifacts supposed to have been obtained in the auriferous gravels are now known to have been washed to the places where they were found by large-scale operations of hydraulic mining.

The fact that the Calaveras skull occurrence, put forward with such care by leading scientists, seemed to be discredited may have had influence in making it appear that other occurrences, especially of flint implements assumed to come from Pleistocene deposits scattered rather widely over the West, were also untrustworthy. It may not be too much to say that Bret Harte's interesting poem dedicated to the Calaveras skull had real influence in retarding advance of knowledge relative to the antiquity of man, especially in the western half of the continent. But the story of this skull was more complicated than we assumed. It now seems that the general record of man's presence over America is also a more difficult problem for investigation than appeared originally.

Investigators who have interpreted the evidence of man's appearance in America as pointing on the whole to a relatively late stage, geologically or historically, have been supported, on one side, by inadequacy of data as to age, presented in such cases as that of the Calaveras skull. They have also pointed out that, as compared with the long series of steps in physical characters and in cultural development represented in the Old World, the remains found in America seem of types such as would be characteristic of the present period, or of a time not later than the latter part of the Pleistocene in the Old World.

In an interesting way this suggestion of advanced physical and cultural type seems to have been supported by evidence from localities widely scattered over the continent. There is of course the argument that advanced physical types of man, such as those of the modern Indian, may have extended back for a much longer period in America than in the Old World, and that along with this advanced physical development the presence of highly developed cultural types might be expected. But the idea of certain early students that "man is cosmopolitan in space and time" is difficult to substantiate by the evidence of distribution of cultures, and especially by the evidence of the geologic history of cultural phases throughout the Old World.

Quite in contrast to the abundance of human relics found at many places in the Old World, information as to the existence of man derived from formations assumed to be of considerable age has thus far been extremely scanty in America. So rare are these occurrences that their discovery has been rather a matter of continual watchfulness than of systematic investigation and excavation. Owing to what might almost be called spontaneous development of interest, the last three decades have, however, brought out numerous occurrences of great significance ranging over a considerable part of the continent. Especially important have been those occurrences associated either with animal remains belonging to extinct faunas or with deposits that can be dated by characteristic phenomena of a glacial epoch. Other cases demanding careful study are those in which either skeletal remains or artifacts have been found buried at depths of 10 to 20 feet in deposits that are not easily identified with accumulations of the present epoch.

Illustration of types of occurrence which demand attention is found in the human remains, described by Sellards, from Florida, in deposits which have the aspect of late Pleistocene and contain a fauna clearly not characteristic of the present period. Of similar significance are evidences of man or his works from caves, such as those in association with ground-sloth remains at Gypsum Cave, Nevada, studied by Harrington and Stock. Another extremely significant occurrence is that excavated by Howard in a cave near Carlsbad, New Mexico, where artifacts are in such a location as to suggest association with a fauna including an extinct horse, an extinct bison, the musk ox, and other forms. Recent discoveries by Howard at Clovis, New Mexico, leave no doubt regarding association of artifacts with remains of the elephant. Of great significance are also the occurrences of finely worked artifacts at Folsom, New Mexico; Frederick, Oklahoma; and other localities in the Great Plains region, discussed by Figgins, Cook, Brown, and others.

Of much importance are also the human skeletal remains, recently described by Jenks, from deposits with a history closely related to the glacial story in Minnesota.

In all of these occurrences there seems such a weight of evidence in favor of association with faunas characteristic of the late Pleistocene, or of location in deposits which are distinctly of pre-Recent type, that the presumption must lean toward recognition of burial of human relics at a time earlier than what we have called the "Recent epoch." The record appears to extend back into a period that is either an older extension of our Recent epoch, or one representing the later portion of Pleistocene time. We may not, of course, avoid consideration of the possibility that many faunal types which have been assumed to be limited to characteristically Pleistocene stages may have lived on into the early part of the present period. Such may be true of cave fauna or of faunas of other types. On the other hand, it is not sufficient to say that all occurrences representing this phase of association are to be explained on the basis of the holding over of Pleistocene types into the present period.

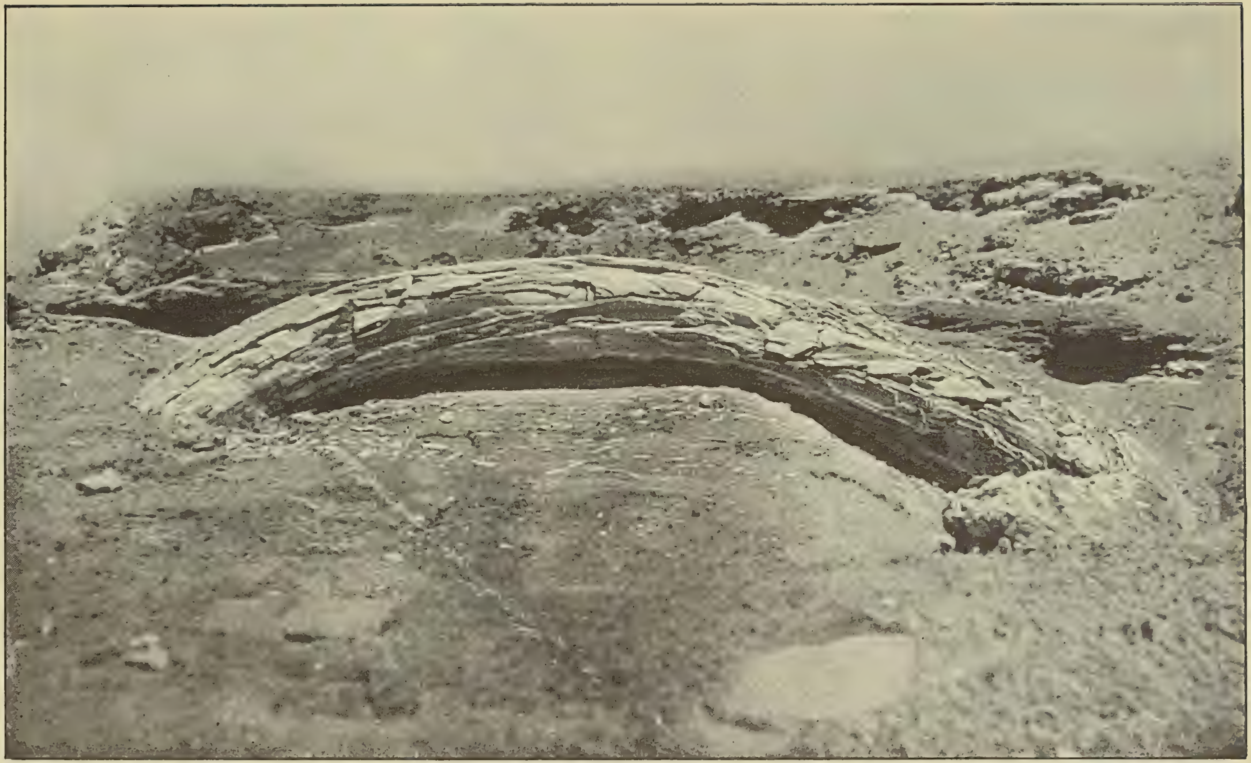
Seen from a point of view already discussed, it is also important to recognize that, on the basis of studies made up to the present time, most if not all of the most ancient skeletal remains found in the New World are of types closely resembling present-day inhabitants of America. More intensive examination of these specimens may reveal a different story. Hitherto, however, examination has not been carried out with the detail desirable for final investigation. It is also true that the artifacts obtained represent what seems an advanced type of work, rather than the rough touch distinctive of early stages of human tool-making activity in the Old World.

Some of the problems which have been involved in discussion of geologic occurrence, faunal association, and development of culture in past decades, we are now beginning to see in a clearer light. It is evident that in the region between late Pleistocene and early Recent time there is much of geologic history of which our knowledge is, to say the least, inadequate. The interesting record of crustal movement, sedimentation, and erosion, such as is represented, for example, on the western border of the continent in this particular section of time, should be the objective of intensive research. It is essential that the geologist give to this study the same kind of concentrated effort that has been bestowed upon comparable time divisions and their geologic representation in Europe.

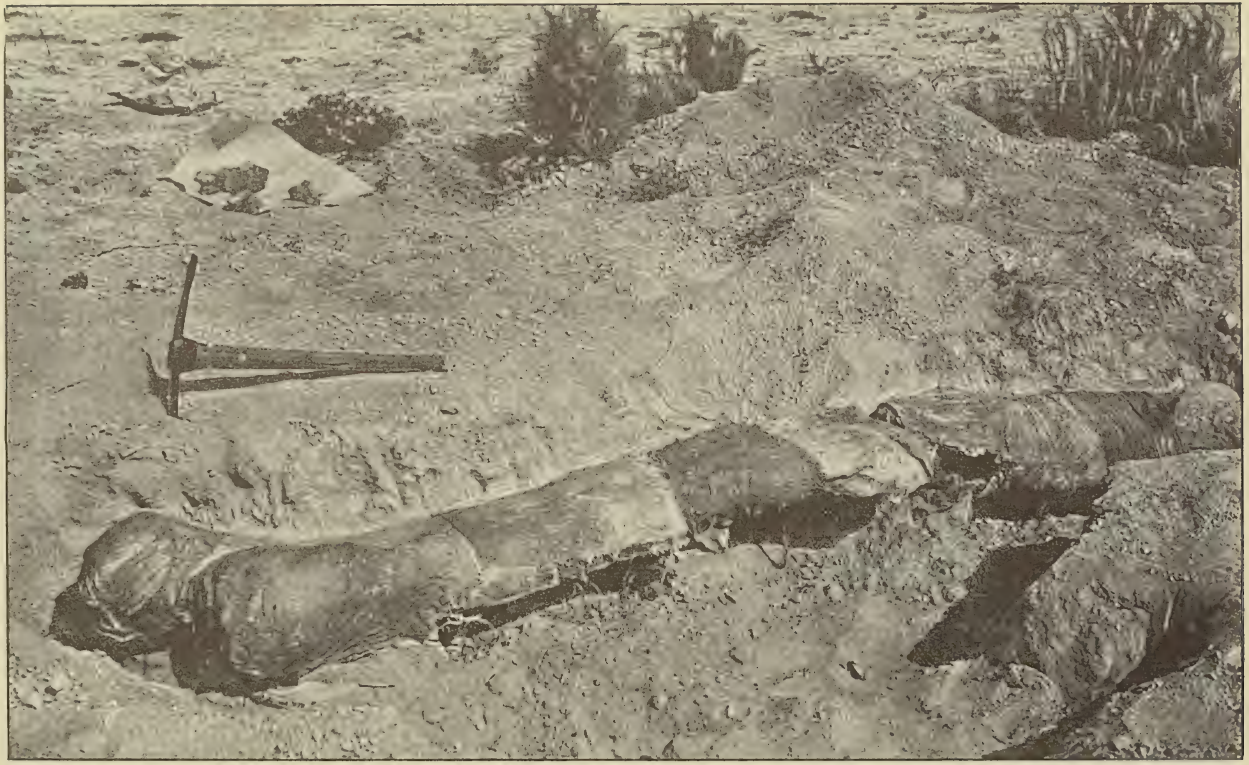
In the same way the association of human remains with faunas that are now extinct is a matter which research over many years has illuminated only in part. The writer has stated on many occasions that the relation between faunas of middle and late Pleistocene and those of early Recent time in the Pacific coast region represents a problem that we have as yet only begun to appreciate. Unless more intensive work is done than has yet been possible, the development of an actual clear sequence of these faunas is something which will not appear until later decades.

The problem presented by cultural types illustrated among artifacts found in the oldest occurrences is also becoming a matter of great interest and suggests the existence of cultural stages whose relation to the known history of early American man we have yet to develop in a wholly satisfactory way.

So, in viewing broadly the question of the antiquity of man in America, it would appear that at this time, in the fourth decade of this century, we are beginning to see more clearly the real nature of the problem. We recognize that, in its way, each of the views presented has points that must be considered. The problem as a whole is more complicated and more interesting than has been assumed. The story as it works out will need intensive cooperative study by archeologist, paleontologist, and geologist. It is also interesting to note that, as the investigation develops, there seems reason to expect that the contribution of study on early man in America will fit itself in a significant way into the story of man for the world as a whole, and that it will illuminate many of the most fundamental aspects of human history.

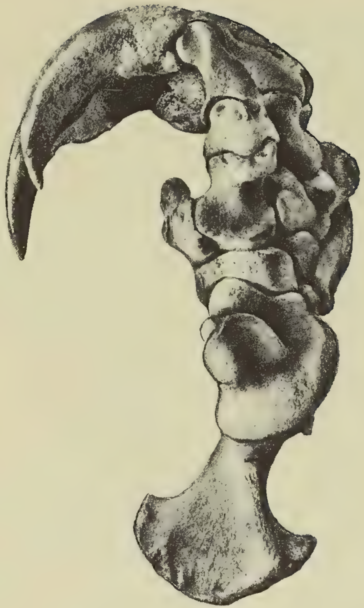


A badly weathered tusk of extinct elephant found in bluish-gray sand near Clovis, New Mexico. This tusk measures approximately 11 feet along the curve, allowing 12 inches for the broken tip.

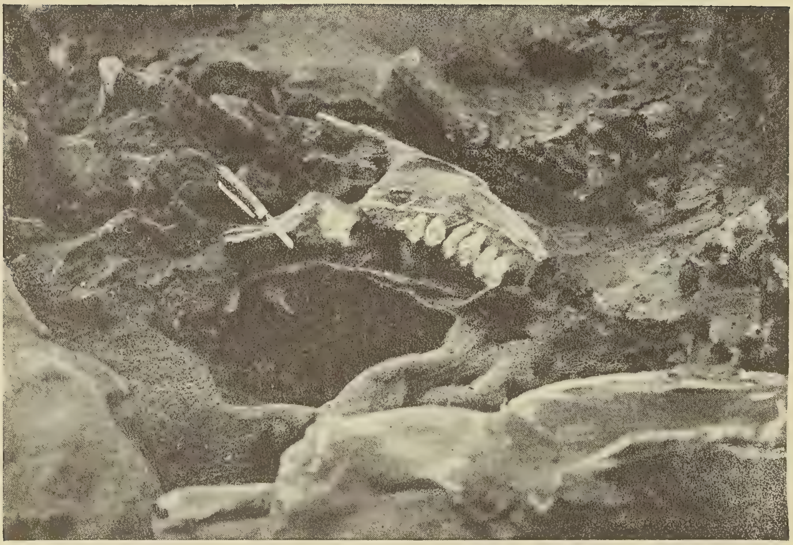


Leg bone of extinct elephant from the Clovis, New Mexico sands. In these sands dart points and scrapers like those shown in succeeding illustrations have been found in association with bones of extinct elephants and bison.

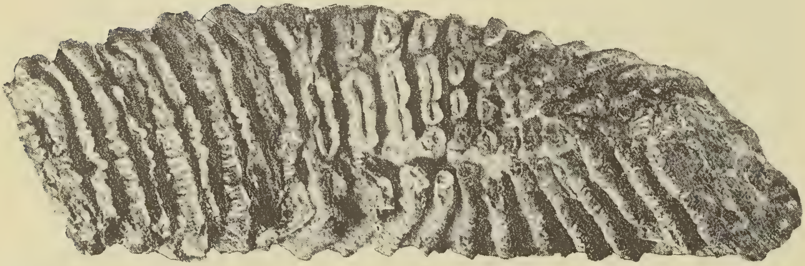
M. R. Harrington holding a claw of a Gypsum Cave ground-sloth. The cave was once occupied by a number of these animals now extinct. Artifacts were also found in the cave in position indicating that man was contemporaneous with the animals.



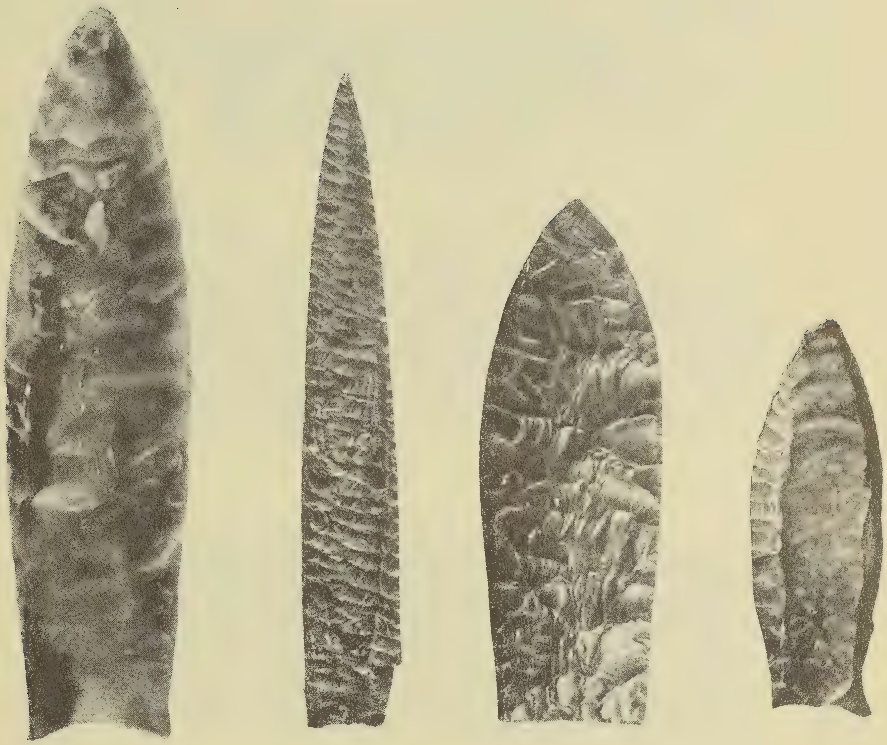
The dorsal view of the right hind foot of one of the Gypsum Cave ground-sloths; the original measured nearly two feet in length. Indication of horny sheaths still adhering to claws can be seen.



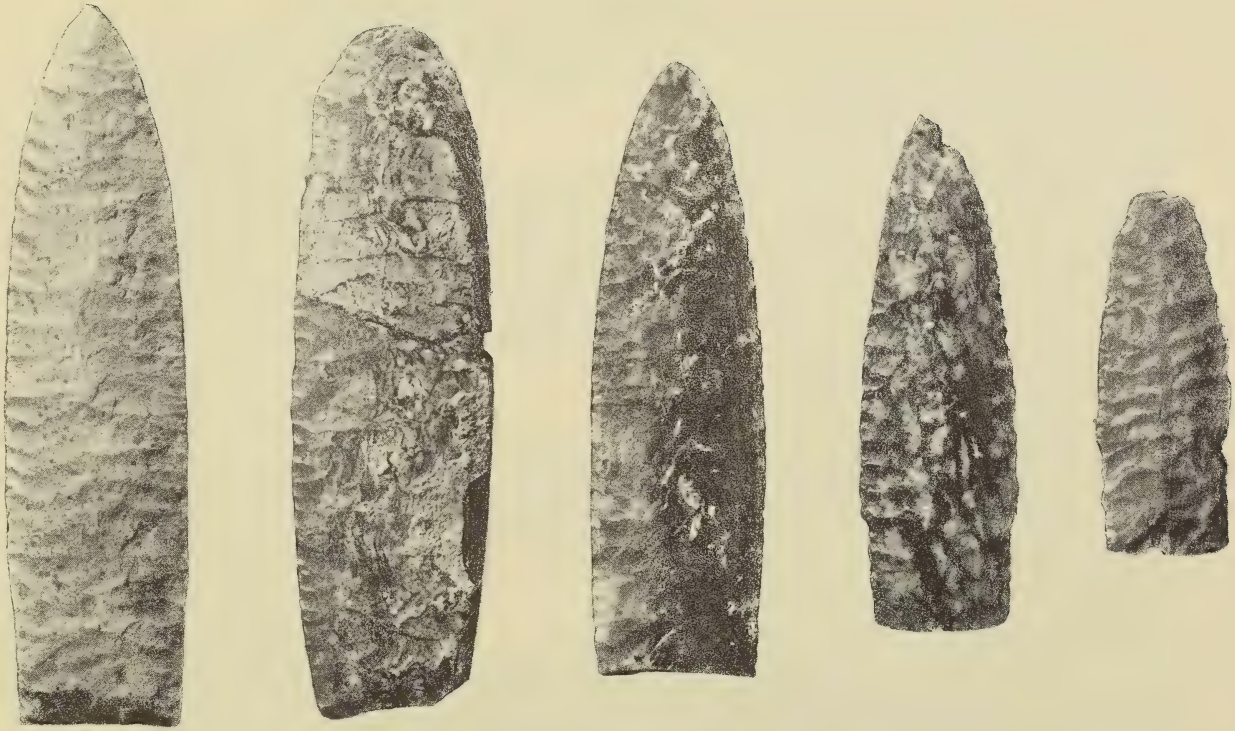
The jawbone of extinct bison found in a gravel pit near Clovis, New Mexico. Charcoal and burned bones, evidence of early man, were also found here.



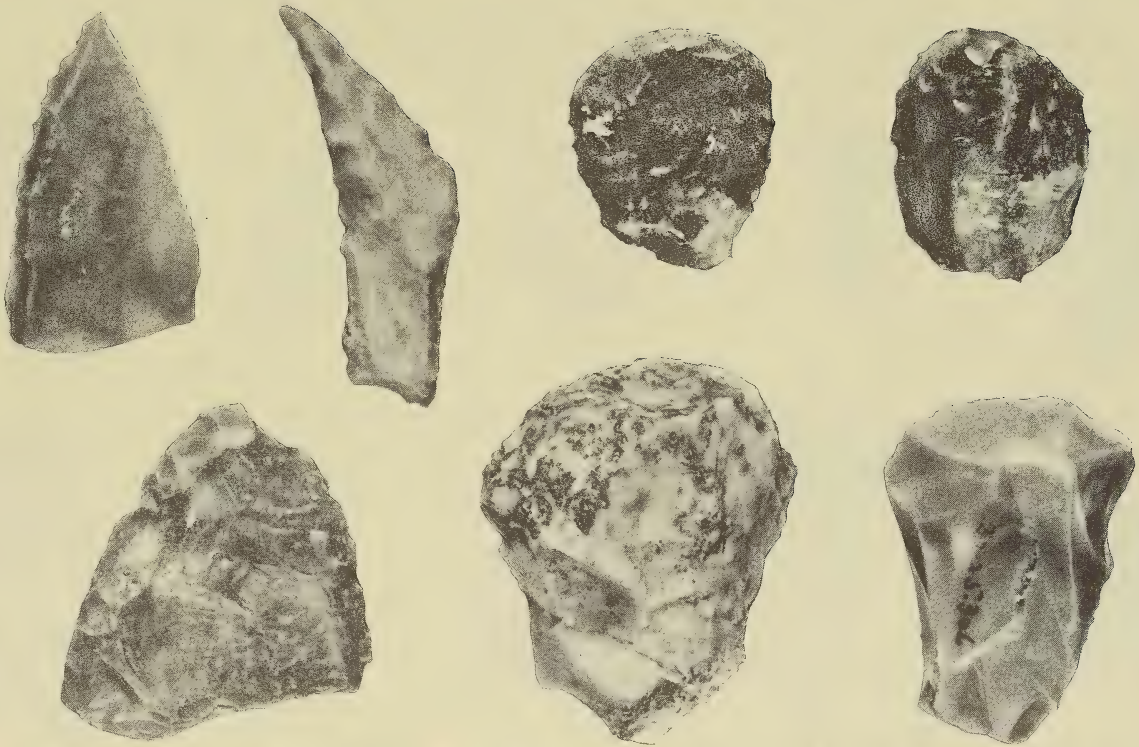
Tooth of extinct elephant from the Clovis, New Mexico, gravel-pit. The number of bones of extinct bison and elephants found in this pit is so great as to suggest that it once may have been a waterhole in which these animals bogged down.



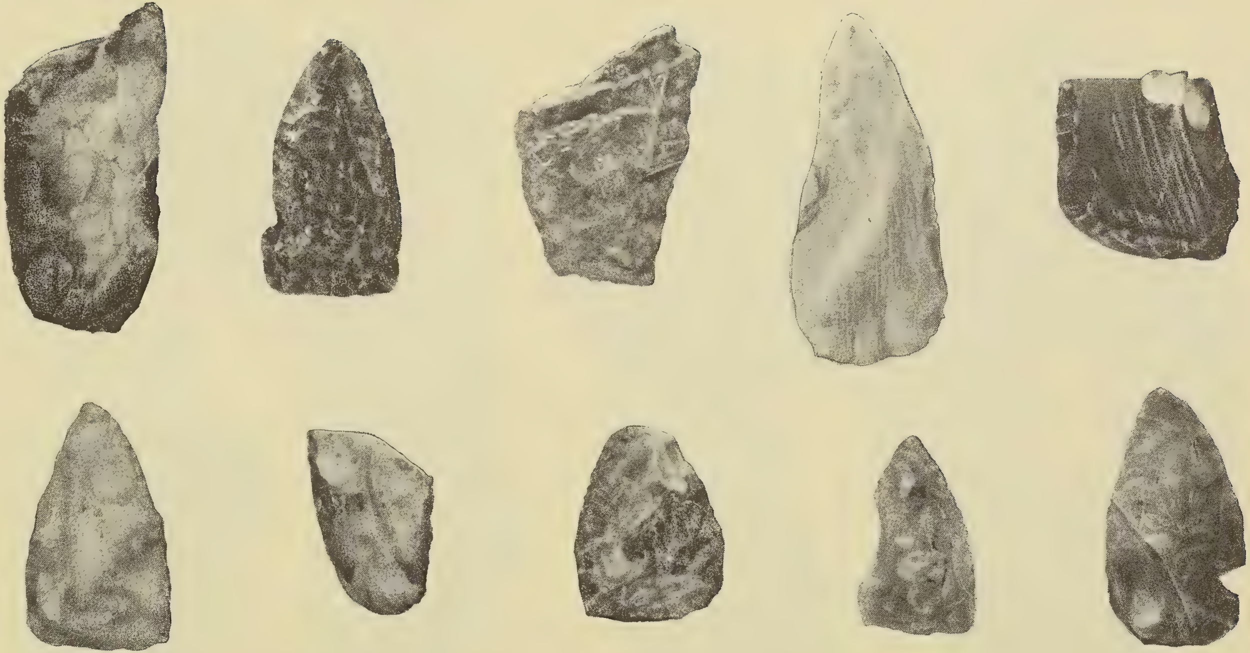
The first artifact to the left is a "Folsom-like" point, somewhat cruder than the so-called "Folsom" type. The second is a "Yuma" type, showing fine, ribbon-like flaking on its face. The third is a knife; and the fourth represents the "fish-tail" type of the "Folsom-like" point.



"Yuma" types of artifacts from the Clovis pits. The flaking is as fine as on the "Folsom" points. These may represent knives of the same peoples who made the Folsom points. The secondary chipping equals that of the Danish and Egyptian Neolithic blades.



Associated with "Folsom," "Folsom-like," and "Yuma" dart points are "scrapers" from the old lake beds near Clovis, New Mexico. These tools were used by primitive people in scraping the flesh from the hides of animals.



These artifacts were found in the bluish-gray sands of one of the old basins at Clovis near the bottom of the deposit in a layer of charcoal, ash, and burned bones. At considerably higher levels in the same basin, bones of extinct elephants and bison were found.

PALAEONTOLOGY OF EARLY MAN

THE series of discussions and conferences on the beginnings of human history initiated here today is of unusual importance by reason of two exceptional conditions. First, the materials to be discussed are presented in person by distinguished investigators coming from some of the most important regions of the entire world; second, because the subjects are considered from a range of viewpoints making possible an unusually clear vision of conditions which obtained on the earth in these early stages of human history.

The coming together of investigators engaged with research in regions of especial interest scattered over the world makes possible a comparison of results of the highest importance at this stage in study of the earliest human history. Consideration of the major problems from the point of view of geology, palaeontology, geography, climatology, general biology, anthropology, archaeology, and general distribution of organisms associated with man, enables us to develop a perspective which will be of great importance in all efforts to understand early human history.

It is difficult for any history to write its own beginnings. But fortunately the touch which every train of events shows with innumerable related or influencing features makes possible some increase in definition of the picture through study of these associated factors. So in the case of the beginnings of human history, contribution from many related subjects has given us invaluable data relative both to the story of man himself and to the setting or environment of man so important in connection with an attempt to visualize the initial steps in our history.

Not the least important of these contributions has been that furnished by a study of the general evolution of organisms in late geological time, including especially those forms which are most

Introductory address before the International Symposium on Early Man, under the auspices of the Academy of Natural Sciences of Philadelphia, March 17, 1937. *Pan American Geologist*, vol. 68, no. 1, pp. 1–3, August 1937. Published under the title "Introductory Remarks" in *Early Man*, pp. 19–22. Philadelphia: J. B. Lippincott Company, November 1937.

nearly related to man and out of which it is to be assumed that the human group would be derived if it be looked upon as the result of evolution rather than of special creation. Intensive studies on evolution of the higher groups of animals on all the continents has fortunately furnished us already with an extremely interesting picture of how life in these higher groups developed through the ages. This picture of the biological process as we find it operating through time is extremely important in connection with any consideration of the story of beginnings or early development of man.

Looking at the materials of this symposium from the purely palaeontological point of view, it is desirable to make record of the fact that the data which we have relative to early man and his history represent the most intensive and careful study that this aspect of science has been able to give. It is the palaeontologist's habit to subject every important fragment that can be discovered to the most careful possible study, with a view to interpreting the remains from every angle of vision. We should expect to find materials representing early man scattered and fragmentary as we go back in time. And we should also expect palaeontologists to bestow upon the materials obtained the most rigid scrutiny that this field of science permits.

With reference to the quantity of material obtained in study of earliest man, although it is true that collectively we have now a considerable group of specimens representing man of early time, we must appreciate the fact that even looking for a needle in a haystack, commonly held to represent the limit of difficulty, might be an easy task compared with the search for remains of early Pleistocene man taking the world as a whole. Or locating that elusive infinitesimal represented by the electron may not represent a more difficult problem than the finding of determinable material of man from the first geological epoch in which his remains are known to occur. The development of techniques which have made possible first the location and next the determination of these materials is, in the judgment of those who have studied this problem, one of the important achievements of science.

In this field of research, as in all others, it is certainly proper, and perhaps desirable, to inquire regarding values which may ultimately be contributed through the information secured. It is easy to see how doubt may be raised concerning the human worthwhileness of investigations which have to do with fragments of human beings from a period so remote that there seems little touch with life of today. And yet there is reason to believe that the contributions of history which present early man with his peculiar characters and his strange setting have had a profound and far-reaching effect upon our conception of man and of his place in the world. The general environment in which man existed in past ages, with a different geography, different climatic conditions, and in the midst of a living world quite distinct from that of today—which presents man himself at a time when his physical characteristics and his intellectual effectiveness differed distinctly from man of the present day—these things collectively have had a deep and lasting influence upon our views concerning the nature of human kind.

There have been few contributions to knowledge influencing thought more critically than these discoveries relating to early man. This being the case, it is desirable that careful consideration be given, first of all, to the data regarding the history discussed as it will be presented by the distinguished investigators coming together at this Academy of Natural Sciences in Philadelphia. And it is important that ultimately we examine the meaning of these facts with relation to the present and future of the human world.

INVERTEBRATE PALÆONTOLOGY

NOTE ON TWO TERTIARY FAUNAS FROM THE ROCKS OF THE SOUTHERN COAST OF VANCOUVER ISLAND

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INTRODUCTORY REMARKS

THE occurrence of fossiliferous horizons of marine Tertiary on the coast of Vancouver Island having received only the briefest mention in geological literature, the following description of some interesting collections recently made on the southern coast of the island by Dr. C. F. Newcombe, of Victoria, is offered as a contribution to our knowledge of the geology and palæontology of this region.

During the years 1894 and '95 several collections of marine Tertiary shells from Vancouver Island were forwarded to the writer by Dr. Newcombe for identification and for determination, if possible, of the age of the rocks in which they occur. The collections were all from two localities, representing different horizons of the Tertiary. The first of these is on Carmanah Point at the entrance to the Strait of Fuca, and the second near Muir and Coal Creeks, in the Sooke District. All the material was collected by Dr. Newcombe, who visited the localities, collecting fossils and studying, where possible, the stratigraphic relations of the fossiliferous beds. Up to the time of Dr. Newcombe's explorations the Tertiary fossils of Vancouver Island seem never to have been systematically collected.

University of California, Bulletin of the Department of Geology, vol. 2, no. 3, pp. 101–108, December 1896.

Carmanah Point

The collection from Carmanah Point represents the older of the two horizons, and is interesting on account of the resemblance it bears to the fauna of Conrad's Astoria Miocene,[1] to the greater, Miocene portion of which Dr. W. H. Dall[2] has given the name Astoria Group.

Occurrence of Fossils.—A section of the rocks near Carmanah Point lighthouse, forwarded to the writer by Dr. Newcombe, shows altogether about 150 feet of sandstone, shale, conglomerate and drift mantle. The occurrence of the fossils is described by Dr. Newcombe in the following note:—

> "The fossils are found chiefly in the conglomerate layers, mostly in the contained boulders, which vary in size from small pebbles to four or five feet in diameter. The boulders, when fossiliferous, are of a bluish grey, fine, and very hard sandstone. The matrix of the conglomerate contains in places large quantities of broken fragments of shells, many resembling species in the boulders, but mostly too much broken up to permit identification. Several large pieces of bored fossil wood project in various parts of the section. Similar rocks extend east and west for some miles, but are very difficult of access except in very calm weather."

Dr. Newcombe's statement that the matrix between the fossiliferous boulders contains "broken fragments of shells, . . . resembling species in the boulders," suggests the idea that the boulders are of concretionary origin. This seems all the more probable as the occurrence of fossils in concretionary boulders is not uncommon at Astoria and at various other points on the west coast, where the later Tertiary rocks are exposed. In answer to a question as to the character of the fossiliferous boulders, Dr. Newcombe stated recently that it is possible that they are concretionary, but he remembers having seen along with them, in the fossiliferous beds, large quartz and diorite pebbles and water-worn boulders. Whether water-worn or concretionary, it is pretty certain that the fossiliferous boulders are all of the same origin, since the matrix in which the fossils are imbedded seems to be the same in all cases. We may safely assume that the species cited here as occurring in the Carmanah Point beds all belong to the same fauna, which may have flourished *in situ* at the time the Carmanah Point sediments were being deposited, or may have lived in an earlier period, at a locality not far distant, from which the fossiliferous boulders were derived for the formation of the Carmanah Point conglomerate.

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[1] Geology of Wilke's Exploring Expedition, 1838–42.

[2] Correlation Papers, Neocene. Bull. 84, U. S. Geol. Surv., p. 225.

List of Species.—The following species[3] from Carmanah Point were identified in Dr. Newcombe's collection.

1. *Nucula divaricata*, Con.
2. *Doliopsis* sp.
3. *Lucina acutilineata*, Con.
4. *Mya abrupta*, Con.
5. *Tellina oregonensis*, Con.
6. *Crepidula rostralis*, Con.
7. *Dentalium substriatum*, Con.
8. *Cerithiopsis oregonensis*, Con.
9. *Priscofusus oregonensis*, Con.
10. *Cardita ventricosa*, Gld.
11. *Tellina albaria*, Con.
12. *Lunatia oregonensis*, Con.
13. *Sinum scopulosum*, Con. (*conf.*).
14. *Cylichna oregona*, Con.
15. *Pectunculus patulus*, Con.
16. *Loripes parilis*, Con.
17. *Cytherea vespertina*, Con. (*aff.*).
18. *Trochita inornata*, Gabb. (*aff.*).
19. *Mytilus edulis*, Linn. (*aff.*).
20. *Turritella* nov. sp.
21. *Cardium* nov. sp.
22. *Cytherea* sp.
23. *Solen* sp.
24. Bored wood, *Teredo* (?) sp.

In addition to this list Dr. Newcombe has sent the following list of species, determined by Dr. W. H. Dall, in a collection made near Carmanah Point in 1890.

1. *Axinus bisectus*, Con.
2. *Chrysodomus* sp. (found in Oregon Miocene).
3. Veneroid (possibly *Clementia*).
4. *Macoma nasuta*, Con.
5. *Venus pertenuis*, Gabb.
6. *Pachypoma biangulata*, Gabb. (*conf.*).
7. *Mytilus edulis*, Linn. (*aff.*)
8. *Pleurotoma* indet.
9. *Teredo* sp.

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[3] The synonym of the species listed, together with descriptions and figures of the new species, will form the subject of a future paper.

Correlation.—Of these species numbers 1–17 of the writer's list occur in Conrad's Astoria Miocene, *Trochita inornata* (No. 18) and forms like *Mytilus edulis* (No. 19) occur in the Miocene of California, Nos. 20 and 21 are new, and the other three forms are doubtful.

Of Dr. Dall's list the *Aximus bisectus* and *Chrysodomus* occur at Astoria. A Clementia-like shell, which was seen in Dr. Newcombe's collection, looked very much like *Cytherea oregonensis*, Con., found originally near Astoria. *Macoma nasuta*, *Venus pertenuis* and forms like *Mytilus edulis*, are found in the Miocene of California. *Pachypoma biangulata* occurs in rocks of doubtful age (Neocene) in California. The species of *Teredo* and *Pleurotoma*, not being identified, need not be considered farther.

The fauna of the Carmanah Point beds seems, on the whole, to be the same as that of Conrad's Astoria Miocene, excluding, however, the lower portion of the latter series, which has been supposed to be of Eocene age.

Sooke District

In 1876 Mr. James Richardson noticed the occurrence of fossiliferous rocks in the Sooke District, and published the following statement regarding them.[4]

> "At the mouth of John's River the lowest beds are grey sandstone, in some places crowded with fossils belonging apparently to three or four species. These are referable to the genera *Ostrea*, *Pecten*, and *Saxidomus* and are either of Tertiary or post-Tertiary age."

In 1892 Dr. W. H. Dall mentioned[5] the occurrence of marine beds of Miocene age near Sooke.

Dr. Newcombe visited the Sooke District in 1893, '94, and '95, collecting in all between twenty-five and thirty molluscan species.

The cliffs, in which the fossils occur, are stated by Mr. Richardson and Dr. Newcombe to show a considerable thickness of soft sandstone, with some conglomerate. The strata do not appear to be greatly disturbed. In places the sandstone is full of fossils, which are often well preserved.

Table of Sooke Fauna.—The following table of species gives, as nearly as can at present be determined, the composition of the fauna of the Sooke beds:—

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[4] Geol. Surv. of Canada Rept. Prog. 1876–77.

[5] Bull. U. S. Geol. Surv., No. 84, p. 230.

	Recent	Pliocene, Calif.	Miocene, Calif.	Miocene. Astoria or Carmanah Pt.	Extinct
1. *Placunanomia macroschisma*, Desh.	*	*	...	...	...
2. *Mytilus edulis*, Linn.	*	*	*	*	...
3. *Cerithidea californica*, Hald.	*	*	*	...	...
4. *Acmæa mitra*, Esch.	*	...	...	...	...
5. *Crepidula rugosa*, Nutt. (*aff.*)	*	...	...	...	...
6. *Pecten æquisulcatus*, Carp. (*conf.*)	*	...	...	...	...
7. *Pecten hastatus*, Sowb. (*conf.*)	*	*	*	...	...
8. *Chrysodomus dirus*, Reeve	*	...	...	...	...
9. *Yoldia impressa*, Con.	*	*	*	*	...
10. *Pectunculus patulus*, Con.	...	*	*	*	*
11. *Trochita inornata*, Gabb	...	...	*	*	*
12. *Sinum scopulosum*, Con. (*conf.*)	...	...	...	*	*
13. *Fusus* nov. sp. (a)	...	...	...	...	*
14. *Fusus* nov. sp. (b)	...	...	...	...	*
15. Patelloid nov.	...	...	...	...	*
16. *Nassa* (?) nov. sp.	...	...	...	...	*
17. *Ancillaria* nov. sp.	...	...	...	...	*
18. *Cytherea* nov. sp. (*a*)	...	...	...	...	*
19. *Cytherea* nov. sp. (*b*)	...	...	...	...	*
20. *Bittium* nov. sp. (?)	...	...	...	...	*
21. *Crepidula* sp.	...	...	...	...	...
22. *Ostrea* sp.	...	...	...	...	...
23. *Cardium* sp.	...	...	...	...	...
24. *Cerithidea* sp.	...	...	...	...	...
25. *Tapes* (?) sp.	...	...	...	...	...

Age and Relationship of Fauna.—In attempting to determine the age of the Sooke beds, a comparison of their fauna with that now existing on the Pacific Coast shows that of the twenty molluscan species determined, eleven, or about fifty-five per cent, are probably extinct, and eight or nine are pretty certainly living. Five species could not be certainly determined and should not be considered. According to the law of percentages as generally used in determining the age of Tertiary faunas, the nearly equal number of living and extinct species makes it impossible to place the beds in either the Eocene or Quaternary. The number of species listed being small, we can not place much dependence in the percentage of living species for accurate determination of the age; it is hardly probable, however, that the Miocene would contain forty-five per cent of living species, that number indicating a period nearer the present time.

Regarding the trustworthiness of the percentage method as applied to west coast geology, even when the number of species at hand is large, it may be stated that, while it is certainly of great value where once standardized, it is doubtful whether the percentages of Recent molluscan species found in the faunas of the different Tertiary periods in other parts of the world would correspond at all to the percentages of modern forms, which existed on the west coast during the same periods. Corresponding to variations, or lack of variation, in topography and climatic conditions, the average percentage of Recent species on the west coast in any given period may have been much larger or much smaller than elsewhere.

Comparing the Sooke fauna with that of well-known Tertiary and post-Tertiary horizons of the Pacific Coast, we find that six or seven of the species are known from the Miocene and about an equal number from the Pliocene, nine species are found in the Quaternary and Recent, and seven or eight are not known to occur elsewhere, either recent or fossil.

The fauna of the Sooke beds, as represented in Dr. Newcombe's collection, is quite different from any of the Oregon or California Miocene or Pliocene faunas known to the writer. The presence of such a large percentage of new forms, and the decided difference of the whole fauna from that of Carmanah Point, of Astoria and of the lower Pliocene of Northern California, are rather surprising when we take into consideration the relation of these faunas to each other. There are common to the Carmanah Point and Sooke beds about five species; two good and three doubtful. This is a much smaller number than we should expect to find if both horizons belong to the Miocene or even if one were lower Miocene and the other lower Pliocene. This may be explained either by supposing the interval between the deposition of the original sediments containing the Carmanah Point fauna and the deposition of the Sooke beds to have been a very long one, allowing time for radical faunal changes, or by supposing considerable topographic and climatic changes to have taken place in a shorter interval, accompanied by immigration of new forms.

Supposing the Carmanah Point and Sooke faunas to have lived at different periods along the shore of the same ocean, we can hardly suppose the latter derived from the Carmanah Point fauna by gradual process of evolution within the limits of the middle Tertiary. Immigration and emigration must have been important factors in the change. Granting even that the greater part of the change was due to migration rather than evolution, the faunal changes, together with the climatic or topographic changes which they must necessarily have accompanied, are such as usually mark the boundaries between geological periods.

The evidence at our command indicates that the Sooke beds are of middle Neocene age, and that the time of their deposition was considerably later than that of the Carmanah Point beds.

University of California, Dec. 1, 1896

NEW SPECIES OF TERTIARY MOLLUSCA FROM VANCOUVER ISLAND

The species here described have already been mentioned by the author as being new forms in a short paper[1] on the age and general character of two Tertiary faunas from the southern coast of Vancouver Island.

These faunas were referred to two horizons occurring at different localities, one at Carmanah Point at the entrance to the Strait of Fuca, the other near Muir and Coal Creeks in the Sooke district. The horizon at the first-named locality was temporarily designated as the Carmanah Point beds, and is correlated with Conrad's Astoria Miocene, excluding the lower portion of his series which has been supposed to be Eocene. The second horizon was named the *Sooke beds*, and is, as nearly as can be determined from the study of the known fauna, of *Middle Neocene* age.

The material on which the descriptions are based was collected by Dr. C. F. Newcombe, of Victoria, B. C., who has kindly permitted the author to study the extensive collections which he has made at both of the above-mentioned localities.

Cytherea Newcombei n. sp.

Shell subquadrate to oval, high, moderately thick, truncated anteriorly. Beaks not prominent. Lunule faintly marked. Surface ornamented with numerous, irregularly placed growth lines and ridges. On some well-preserved specimens a large number of very faint radial lines are visible. Length of large specimen 70 mm., breadth 55 mm. Hinge of right valve with three cardinal teeth and a short pit for the anterior lateral tooth of the opposite valve. This pit for the reception of the anterior lateral tooth is shallower and much shorter than in the following species.

Locality: Sooke beds, Vancouver Island.

Nautilus, vol. 11, no. 6, pp. 64–65, October 1897.

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[1] Note on Two Tertiary Faunas from the Rocks of the Southern Coast of Vancouver Island. Bull. Geol. Dept. Univ. of Calif., vol. 2 no. 3.

Cytherea vancouverensis n. sp.

Shell oval, narrowly rounded anteriorly. Beaks prominent. Lunule well marked. The somewhat weathered surface of the shells ornamented by numerous, irregularly placed growth ridges. Length of type specimen 62? mm., breadth 48 mm. Hinge of right valve with three cardinal teeth and a long, deep tooth pit for the reception of the anterior lateral tooth of the left valve. Pit between the two anterior cardinal teeth of right valve ordinarily narrower and deeper than in *C. Newcombei*.

Locality: Sooke beds, Vancouver Island.

Patella geometrica n. sp.

Shell large and heavy, up to 50 mm. or more in length, suborbicular. Apex elevated, well forward. Surface ornamented by about twenty broad, strong, radial ribs, which are much wider than the interspaces. Radial ribs crossed by numerous, prominent, narrow, sometimes leafy, transverse ridges.

Locality: Sooke beds, Vancouver Island.

Turritella diversilineata n. sp.

Shell medium size. The imperfect type specimen shows seven flattened whorls, which are strongly bevelled below. Flattened sides ornamented by five revolving ribs of which the lowest, standing on the angle of the whorl, is much stronger than the others. On some of the whorls there are indications of revolving sculpture on the bevelled surface between the lowest rib and the suture.

Locality: Carmanah Point, Vancouver Island.

Nassa Newcombei n. sp.

Shell between 25 and 30 mm. in length. Whorls five, with a well marked shoulder, ornamented by numerous longitudinal and transverse ribs which give the middle portion of the whorls a tesselated appearance. The upper revolving rib, which forms the angle of the shoulder, is stronger than the others and is usually separated from them by a distinct groove. On the last whorl the transverse ribs (about 25) are dominant on the upper portion, excepting the shoulder, and are latticed by the less conspicuous revolving sculpture. On the lower portion of the whorl the transverse ribs disappear, leaving the well-defined revolving ribs uninterrupted.

Bullia buccinoides n. sp.

Shell ovate, whorls five. Spire short. Suture partially or entirely covered. Aperture with strong anterior notch. Outer lip thin, sharp; inner lip with broad callus. Length 25–30 mm.

Locality: Sooke beds, Vancouver Island.

University of California, August, 1897

THE DISTRIBUTION OF THE NEOCENE SEA-URCHINS OF MIDDLE CALIFORNIA, AND ITS BEARING ON THE CLASSIFICATION OF THE NEOCENE FORMATIONS

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Introduction

Of the numerous invertebrate forms known from the marine Neocene of California there are none which better aid the geologist in the determination of horizons than the echinoids. Though Neocene molluscan remains are plentiful, they are not always characteristic nor are they usually in a good state of preservation. The sea-urchins, when present at all, are usually abundant and well preserved and, having in most cases a short geological range, are of more than ordinary value in geological work.

At the present time there are eight species of sea-urchins known from the Neocene formations of California, all of which, on account of their abundance and their good state of preservation, were among the first fossil forms to be described from this coast. They all belong to the Clypeastridæ, being distributed among the genera, *Echinarachnius*, *Scutella*, *Astrodapsis*, and *Clypeaster*. The species have generally been referred to the geological periods as follows:

Quaternary—*Echinarachnius excentricus*, Esch.

Pliocene	*Echinarachnius excentricus*, Esch. *Scutella interlineata*, Blake. *Astrodapsis Whitneyi*, Rém. *Astrodapsis tumidus*, Rém.

University of California, Bulletin of the Department of Geology, vol. 2, no. 4, pp. 109–118, May 1898.

Miocene	*Astrodapsis tumidus*, Rém.
	Astrodapsis Antiselli, Con.
	Scutella (*Clypeaster*) *Gabbi*, Rém.
	Echinarachnius (*Scutella*) *Gibbsi*, Rém.
	Clypeaster ? (*Echinarachnius*) *Brewerianus*, Rém.

From the observations of the writer it appears that the geological classification of these species, as indicated above, may not be accepted without certain modifications, which are dependent on the local classification of Neocene formations. In order to discuss the subject intelligently it will be necessary first to notice briefly the occurrence of the species individually.

Occurrence and Range of Species

Echinarachnius excentricus and *Scutella interlineata* are both found in the sea cliffs of Seven-mile Beach, south of San Francisco, which have been referred to the Merced series (Pliocene). There the first-named species occurs near the top of the section. If the upper fossiliferous beds of the Seven-mile Beach section are Quaternary, as many of the writers on the palæontology of this series (Rémond,[1] Gabb,[2] Ashley[3]) have suggested, it will probably be shown that *E. excentricus* does not occur there below the base of the Post-pliocene. It is not impossible, however, that it belongs also to the top of the Pliocene, since the line drawn between the Quaternary and the Pliocene near the top of the cliff section is to some extent an arbitrary one.

Besides the occurrence at Seven-mile Beach, *E. excentricus* is known from the Quaternary of Santa Barbara and San Pedro and also from San Fernando, Los Angeles County. At the last-named locality it is said to be in the Pliocene. Satisfactory information regarding these occurrences has not been obtained by the writer, but, judging from the state of preservation of the specimens examined, they are all either of late Pliocene or of Quaternary age.

Scutella interlineata is fairly common throughout the greater portion of the Merced. It is not rare near the base of the series at the typical locality, on Seven-mile Beach, and is found at intervals up to a point considerably beyond the middle of the section.

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[1] Geol. Surv. of Cal. Geology, Vol. I, p. 79.

[2] Geol. Surv. Cal. Palæontology, Vol. II, p. 110.

[3] Proc. Cal. Acad. Sc., Second Ser., Vol. V, p. 330.

It is known also from Humboldt County, California, where it is associated with a fauna similar to and probably of the same age as that of the lower portion of the Merced near San Francisco.

The remaining species which have been considered as Pliocene, viz., *Astrodapsis Whitneyi* and *A. tumidus*[4] occur along with *Scutella* (*Clypeaster*) *Gabbi* in a series of strata which is well developed on the south shore of San Pablo Bay, at Kirker's Pass north of Mt. Diablo, and in the hills to the south and west of Mt. Diablo. At these places they are associated with a fauna not known at other horizons, containing among other characteristic forms, *Pseudocardum Gabbi*, *Pecten Pabloensis*, *Pinna Alamedensis*, *Mulinia densata*, *Trochita* n. sp., *Littorina Remondi*, and *Trophon ponderosum*.

Within this series the *Scutella*, wherever present, occupies a lower horizon than *Astrodapsis*. In a remarkably well-exposed cliff section, near the Union Oil Refinery, on the south shore of San Pablo Bay, the best-known example of the zonal distribution of these sea-urchins is very clearly shown. At this point the strata are standing almost vertically, exposing a thickness of nearly fifteen hundred feet. At the bottom or north side of the section *Scutella* is very abundant and *Astrodapsis* is absent. Two or three hundred feet farther up *Scutella* disappears and *Astrodapsis* appears. From that point to a distance of nearly one thousand feet higher *Astrodapsis* is abundant, *Scutella* apparently not passing beyond the stratum at which *Astrodapsis* appears. The two species are, however, abundant in beds less than ten feet apart, and may be found to overlap. At other localities in this formation the same sequence of genera was observed. The exact relations which the two species of *Astrodapsis* bear to each other in time have not yet been determined, but *tumidus* is possibly the older. The *Astrodapsis* forms are perhaps the more characteristic of the formation, as the lower beds with *Scutella* are sometimes absent, while the upper and much thicker *Astrodapsis* beds are usually present.

The third species of *Astrodapsis*, viz., *Antiselli*, which has been supposed to be Miocene, is possibly identical with one of the other two forms. It occurs[5] in San Luis Obispo and Kern Counties, where it is associated with a fauna much like that found with *A. tumidus* and *Whitneyi.*

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[4] *A. tumidus* occurs also in the southern part of the state, in Santa Barbara and Ventura Counties.

[5] Pacific R. R. Rep., Vol. 7, p. 196.

Of the remaining forms referred to the Miocene, *Echinarachnius* (*Scutella*) *Gibbsi* is known from Neocene strata, near Buena Vista Lake, Kern County.[6] It is also listed by Ashley[7] from his transition beds near Santa Cruz, where it is said to be associated with *S. interlineata.*

The oldest of the Neocene sea-urchins, *Clypeaster?* (*Echinarachnius*) *Brewerianus* is a common species in the upper portion of a voluminous series in Contra Costa County, generally recognized as Miocene, which at Walnut Creek, near Mt. Diablo, underlies the formation containing *Astrodapsis.*

From what has already been stated, regarding the distribution of the Neocene and Quaternary Echini, it will be seen that there are in the middle Californian region at least four distinct sea-urchin horizons above the middle of the Miocene. The zone of *Clypeaster?* (*Ech.*) *Brewerianus,* in the upper portion of the Miocene of Contra Costa County, is the lowest. That of *Echinarachnius excentricus,* in the Quaternary, perhaps including the latest Pliocene, is the highest. Between these lie the zone of *Scutella interlineata,* in the Merced series, immediately below the Quaternary of Seven-mile Beach, and the beds with *Astrodapsis* and *Scutella* (*Clypeaster*) *Gabbi,* above the recognized Miocene of Contra Costa County.

Both of these last-mentioned, intermediate horizons are generally referred to the Pliocene, though the age of both has been variously determined by different investigators. It is thought that the distribution of their characteristic sea-urchins and the associated molluscan forms throws some light on the question of their relative age.

The San Pablo Formation and Its Geologic Relations

The series of strata characterized by the presence of *Astrodapsis* and *Scutella* (*Clypeaster*) *Gabbi* may, with reference to its more important features, be treated as a distinct formation, and will be referred to in this paper as the *San Pablo formation.*

Faunal and Lithological Characters of the San Pablo.—At all of the localities at which the San Pablo is known, it is characterized faunally by the presence of a peculiar assemblage of genera and species, in which *Astrodapsis* is the most abundant and easily recognized form. The fauna is known so far by about fifty species, of which nearly one-third are peculiar to these beds, about one-fourth are known also from the Contra Costa County Miocene, and one-sixth from the Merced. A little less than one-half of the known forms are extinct. The number of species made use of in this calculation is, unfortunately, not large, but the proportions have been about the same in all of the collections made at different localities by Gabb, Turner, and the writer, so that we may consider them as approximately indicating the relations of the *most vigorous* part of the then existing fauna to that of the nearest periods.

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[6] Proc. Cal. Acad. Sc., Vol. III, 1863–67, p. 13. Rémond.

[7] Proc. Cal. Acad. Sc., Second Ser., Vol. V, p. 328.

The sea-urchins form the most prominent organic feature of the formation, neither of the *Astrodapsis* species being found outside of it. The zone of *Scutella* (*Clypeaster*) *Gabbi* is not always present, but may be considered as belonging to the formation.

Lithologically, and even scenically, the strata of this formation are readily distinguished from those of the adjoining groups. A considerable thickness of tuffs and ashes, most prominent in the upper portion of the formation, and the peculiar weathering of the standstones, are constant and striking characters of the greatest value in working at points where fossil remains are rare or absent.

Relation of San Pablo to Contra Costa County Miocene.—The relations of this formation to the Contra Costa County Miocene are well shown at Walnut Creek, where the highly disturbed Miocene-bearing *Clypeaster?* (*Ech.*) *Brewerianus* is accompanied by the Astrodapsis-bearing beds, standing at the same angle and seemingly conformable on it. *Scutella* (*Clypeaster*) *Gabbi* has not been seen at this point, though it may be present below the *Astrodapsis* beds. It is known, however, on the opposite side of the valley, where it seems to be low down in the formation.

At San Pablo Bay the beds bearing *Astrodapsis* and *Scutella* form a wide syncline, the bottom of which is the *Scutella* zone. On this lie the *Astrodapsis* beds with tuffs and ashes above. The northern limb of the syncline, resting on the upper portion of the Contra Costa County Miocene, is in almost vertical position. On the southern side of the syncline the strata stand at a much lower angle, about twenty-five degrees.

Though no distinct unconformity between the lower portion of the

San Pablo and the Contra Costa County Miocene has been seen, a break is indicated at several localities. At present it is not possible to draw a sharp line between the two formations at all localities. Where ash and tuff beds are present in the lower portion of the San Pablo the separation is easily made.

Relation of San Pablo to Merced.—The stratigraphic relations of the San Pablo to the Merced are not yet definitely known; the two formations, though occurring only a few miles apart, have not yet been seen in contact.

Faunally the San Pablo does not appear to be as closely related to the Merced as it should be if the two belong to the same formation or the same period, it is in fact not so closely related to the Merced as to the Contra Costa County Miocene. At San Pablo Bay the formation shows more than one thousand feet of very fossiliferous sandstones containing an abundance of echinoids, all of which are different from those of the Merced. The Merced section south of San Francisco shows several thousand feet of fossiliferous sandstones with echinoids but not a single specimen of any of the San Pablo species has been found among them. The molluscan faunas of the two formations, though not mutually so exclusive as the Echinoderms, are very different. Not more than one-fifth of the fifty species known from the San Pablo occur in the Merced. It is difficult to conceive of any way in which two shallow-water, marine faunas so different as these could exist within a few miles of each other, through the length of time required in forming more than one thousand feet of sandstones, without their becoming mingled to some extent, and mingling of their most characteristic forms we do not find.

So far as faunal proof is concerned, it is not easy to believe that the Merced and San Pablo have been deposited at the same time, and any stratigraphic evidence which may later tend to indicate their contemporaneity will show the existence of biological conditions in Middle California, during that period, radically different from any which have ever been met with elsewhere.

Age of San Pablo.—If the Merced and San Pablo are not of the same age, both faunal and stratigraphic evidence would point toward the latter as the older of the two. The fauna of the San Pablo is more closely related to that of the Miocene of Contra Costa County than to the Merced fauna. Stratigraphically the formation shows a much greater amount of deformation than the Merced, and where the upper beds are overlaid by the Quaternary a much more pronounced unconformity is seen than has so far been shown to exist between the Merced and the Quaternary. Lithologically there is a noticeable difference between the two, as the great beds of ash and tuff so characteristic and widespread in the San Pablo appear to be entirely absent from the Merced. The only distinctly volcanic deposit in the whole cliff section at Seven-mile Beach is a thin layer of ash, about two hundred feet above the most fossiliferous Quaternary horizon.

The San Pablo formation has been called Miocene by Conrad[8] and Gabb[9] where it is exposed on the shore of San Pablo Bay, Miocene by Gabb[10] at Walnut Creek, where it contains the same fauna and shows the same sequence of beds, and Pliocene by Gabb[11] at Kirker's Pass, to the north of Mt. Diablo, where the beds are indistinguishable faunally, lithologically, and otherwise from those at Walnut Creek. It appears then that at different localities the same formation has been referred to different periods.

The Merced series was determined as Pliocene by Rémond,[12] Gabb,[13] and Lawson,[14] has been considered by Ashley[15] as mainly Pliocene, but probably including also some Miocene, while Lindgren[16] has recently suggested that it may be correlated with the Pleistocene of the Sierra Nevadas.

If the Merced series be Pliocene, the San Pablo must be below the upper Pliocene at least. It has already been shown to rest above what has been considered Miocene in Contra Costa County. In other words, it probably represents middle Neocene. Such a determination of the age of this formation, it will be noticed, was, to some extent, foreshadowed by the reference of different localities on the same beds indifferently to the Miocene or the Pliocene, by the earlier writers on the Geology of this region.

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[8] Pacific R. R. Rep., Vol. VI, pp. 69, 71.

[9] Geol. Surv. of Calif. Palæontology, Vol. II, p. 109.

[10] *Ibid.*, p. 2.

[11] Geol. Surv. of Calif. Geology, Vol. I, p. 31.

[12] *Ibid.*, p. 79.

[13] Geol. Surv. of Calif. Palæontology, Vol. II, p. 110.

[14] Bull. Geol. Deptm. Univ. of Calif., Vol. I, p. 143.

[15] Proc. Calif. Acad., Second Ser., Vol. V, p. 312.

[16] Jour. Geol., Vol. IV, p. 905.—As far as the relative ages of the horizons are concerned, Mr. Lindgren's correlation may be correct. This does not, however, by any means necessitate the reference of the Merced to the Pleistocene, as its marine fauna, which has generally been taken to indicate late Tertiary age, really furnishes more data of value in age determination than could be obtained from the fresh-water formations of the Sierra region.

Classification of the Neocene of Middle California

The following table, giving the occurrence and geological range of the echinoid species known above the middle Neocene, illustrates the faunal and the probable time relations of the formations in which they occur to each other.

Quaternary—*Echinarachnius excentricus*, Esch.

Merced	*Echinarachnius excentricus* Esch.(?) *Scutella interlineata*, Blake.
San Pablo	*Astrodapsis Whitneyi*, Rém. *Astrodapsis tumidus*, Rém. *Scutella* (*Clypeaster*) *Gabbi*, Rém.
Contra Costa County Miocene	*Clypeaster?* (*Echinarachnius*) *Brewerianus*, Rém. *Echinarachnius* (*Scutella*) *Gibbsi*, Rém.(? ?)

The Contra Costa County Miocene represents a large portion of the Lower Neocene. Whether it includes all of the Miocene is uncertain. The Merced certainly includes a large portion of the Upper Neocene, but how much is not yet determined. The San Pablo probably represents middle Neocene. It may be found to fall principally within the limits of the Miocene, and probably does not represent a very large portion of the Pliocene. The more exact correlation of these horizons with the Neocene periods of eastern United States and Europe can be accomplished only when our knowledge of the Tertiary faunas of the Pacific Coast is much more complete than at present.

The intercalation of the San Pablo formation between the Contra Costa County Miocene and the Merced Pliocene adds to the already long Tertiary era of California a period of sedimentation, during which at least fifteen hundred feet of strata were deposited. The thickness of the Tertiary section and the number of physical and organic changes, which took place in that era on the Pacific Coast, indicate that the general tendency has been to underestimate rather than overestimate the relative length of Tertiary time.

CORRELATION OF THE AURIFEROUS GRAVELS WITH THE COAST RANGE NEOCENE

For a number of years the relation of the auriferous gravels of the Sierra Nevadas to the marine deposit of the Coast Ranges has furnished one of the most important problems in Californian geology. The correlations that have so far been made have been based largely on comparisons of fossil plants. The plant remains from the Coast Ranges, which have been made use of in these correlations, have been obtained at Kirker's Pass, the Railroad Ranch on the western slope of Mt. Diablo, and Corral Hollow near Livermore Pass. The specimens from Kirker's Pass and Railroad Ranch are from the San Pablo formation. Part of those from Corral Hollow are in a peculiar matrix not known to the writer outside of the San Pablo. The flora is much the same at all three localities. To this flora that of the auriferous gravels shows a considerable degree of relationship. It is probable that the difficult problem of the more exact determination of the age of the auriferous gravels will be most satisfactorily solved through comparison of their flora with that of the San Pablo formation.

University of California, May, 1898

THE TERTIARY SEA-URCHINS OF MIDDLE CALIFORNIA

CONTENTS

Plates XXI–XXII

I. Introduction 1672
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I. Introduction

In the course of an investigation of the invertebrate faunas of Middle California, the writer has found the existing figures and descriptions of the sea-urchins either incomplete or inaccurate to such an extent as to make desirable their reintroduction to those interested in the palæontology of this region. The writer by no means desires to cast reflections on the work of those who first brought the species to light, realizing that with abundant material at hand it is much easier to revise than is the work of original description.

Both geologically and biologically the sea-urchins are among the most deserving of attention of the Californian invertebrates. The comparatively short vertical range of the species, together with their usually good preservation, makes them admirable horizon determiners, while the intimate relationship of some of the forms to each other indicates considerable possibilities in the study of the history and evolution of the clypeastroid branch of the class on this coast, when the faunas of adjoining regions are better known.

II. History and Relationships of Species

The one new species, *Schizaster Le Contei*, Pl. XXI, fig. 1, here added to the list of forms known from Middle California, is of special interest, as it occurs in the lowest Tertiary, Martinez, and represents a family not known in this region later than that time. It seems

Proceedings of the California Academy of Sciences, ser. 3, Geology, vol. 1, no. 5, pp. 161–174, pls. XXI, XXII, March 6, 1899.

to be confined to the Martinez and serves as a characteristic fossil of that formation.

The Tejon formation, resting on the Martinez and forming the upper portion of the Eocene on the Pacific Coast, is not known to contain any echinoid remains, though they may be expected to appear in later collections.

In the Miocene the Clypeastridæ begin and they continue as the only representatives of the class up to the beginning of the Recent period.[1] The oldest certainly known form of this family is *Clypeaster* (*?*) *Brewerianus*,[2] Pl. XXI, fig. 2, of the Contra Costa County Miocene. This species is small and shows no specialized characters, and, as will be shown later, is probably the ancestor of some of the younger forms.

In what have been considered the lowest beds of the San Pablo formation, immediately overlying the Miocene of Contra Costa County, is found the oldest species of the more specialized division of the Clypeastridæ included in the subfamily Scutellinæ. This species, *Scutella Gabbi*,[3] Pl. XXII, fig. 5, is structurally considerably removed from *Clypeaster Brewerianus* and it is doubtful whether they are nearly related. The *Scutella* is probably an immigrant from some other region.

Immediately above the *Scutella* beds the characteristic San Pablo species, *Astrodapsis tumidus*, Pl. XXI, fig. 3, is very abundant. The *Scutella* and *A. tumidus* have been seen in abundance within less than ten feet of each other and may be found to overlap. *A. tumidus* does not show much affinity to *S. Gabbi*, but is closely related to the older form, *Clypeaster Brewerianus*. From this species it is distinguished mainly by the strong relief of the petals, and it is probable that *C. Brewerianus* is the ancestor of *A. tumidus*. Since in the sequence of strata the beds with *S. Gabbi* lie between those containing these two species, and *Clypeaster* was absent during the intervening period, the modification or evolution was probably brought about in some other region, *Astrodapsis* afterwards coming in to replace the disappearing *Scutella*. Closely related to *A. tumidus* is the larger and thinner *A. Whitneyi*, Pl. XXI, fig. 4, which probably belongs to the later portion of the San Pablo. Both species were confined to this epoch, and with their extinction the more generalized Clypeastroids disappeared from this region. Along the line of descent from *Clypeaster Brewerianus* through *Astrodapsis tumidus* to *A. Whitneyi* the gradual increase in size is quite noticeable. The maximum diameter of the first species is 33 mm., of the second 45 mm., and of the third 60–65 mm.

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[1] A new species of regular sea-urchin has recently been discovered by Dr. H. W. Fairbanks in the Miocene of southern California. Such forms may also have been represented in middle California, but as the middle and southern portions of the State show in general quite different faunas, we cannot from this occurrence draw any definite conclusions as to the existence of such forms farther north.

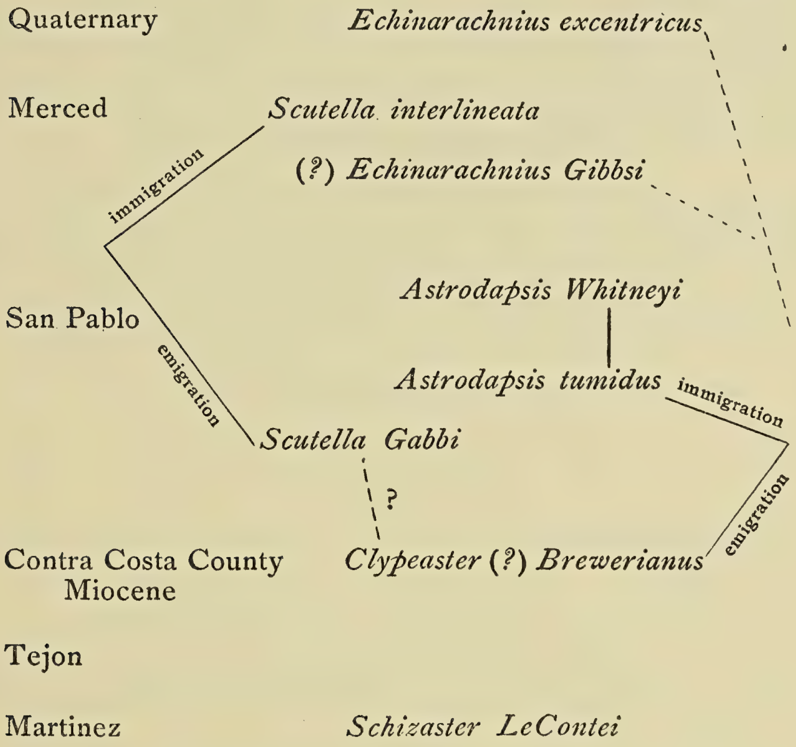
[2] *Echinarachnius Brewerianus* of earlier writers.

[3] *Clypeaster Gabbi* of earlier writers.

During the Merced epoch, following the San Pablo, the Scutellinæ reappear, represented by *Scutella interlineata*, Pl. XXII, fig. 6. This form shows considerable resemblance to *S. Gabbi* and has in common with it the supramarginal anus. *S. interlineata* differs from *S. Gabbi* in being much larger, in the position of the apical system, which is quite eccentric, and in the more pronounced supramarginal character of the anus. These differences are in the direction of greater specialization, except the position of the anus. This opening is travelling back from the lower surface toward the apical shield. Taking into consideration the points of relationship of these species, the fact that the differences may be due to specialization of the older form, and the order of occurrence of the two, it is probably safe to assume that *S. interlineata* is a modified descendant of *S. Gabbi*.

In the Quaternary deposits *Scutella* is replaced by an *Echinarachnius* which is a common form at the present time. This species, *E. excentricus*, Pl. XXII, fig. 8, is probably nearly related to *E. Gibbsi*, Pl. XXII, fig. 7, a form cited from the middle or later Tertiary. *E. Gibbsi* occurs near Buena Vista Lake, Kern County, in deposits which have been referred to the Miocene, and is also cited by Ashley from his transition beds between the Merced and the Miocene near Santa Cruz. This species much resembles the *excentricus*, but shows a greater degree of eccentricity of the apical system than is found in that species. The high degree of specialization in *E. Gibbsi* is not easily explained when we consider that it is the older form. As both forms are immigrants, and as their life-periods do not appear to overlap in this region, they are probably derived from a common stock, less specialized than either form, which lived in some other Pacific region during the middle Tertiary.

The table on the page opposite illustrates the occurrence and probable relationships of the known species of middle Californian sea-urchins. Unbroken lines connecting species indicate such structural and successional relationship as suggests descent. Dotted lines indicate doubtful descent or doubtful genetic relationship.



III. Description of Species

Genus **Schizaster** *Agassiz*

Schizaster Le Contei, sp. nov.

Plate XXI, Figs. 1 and 1*a*

Schizaster, sp., Journ. Geol., Vol. V, p. 773, Dec., 1897.

Small forms averaging a little less than 20 mm. in length. The largest specimen measured is about 23 mm. long. Test distinctly notched anteriorly by the groove of the anterior ambulacrum, truncated posteriorly; upper surface much elevated, with a sharp ridge running from the apical system to the posterior end, summit situated far back. Apical system eccentric, posterior, anterior to the summit.

Ambulacra broad, sunken; anterior laterals reaching a little more than half way to the margin; posterior laterals very short, less than half the length of the anterior pair, sometimes almost circular in outline. Ambulacral pores elongated, apparently yoked.

Mouth opening well forward, broad, two-lipped. Anus high up on the truncated posterior end.

Numerous large spines much like those of *Schizaster* have been found at one locality in the Martinez, but if they belong to this genus at all they were probably derived from another and much larger species. Tubercles larger on the actinal surface. Peripetalous fasciole quite distinct on one specimen. Traces of what appears to be the lateral fasciole have been seen beneath the anus.

Though crushed fragments of this species have been known to the writer for some years, the first recognizable specimens were discovered by the members of the class in palæontology, in April, 1897.

Not rare in the Martinez in Contra Costa County. Specimens preserved only as impressions or casts, usually badly crushed.

Genus **Clypeaster** *Lamarck*

Clypeaster (?) Brewerianus *Rémond*

PLATE XXI, FIG. 2

Echinarachnius Brewerianus RÉMOND., Proc. Cal. Acad. Sci., Vol. III, 1863–67, p. 53.

Echinarachnius Brewerianus. Figured by GABB., Geol. Surv. Cal., Palæontology, Vol. II, 1869, p. 36, Pl. XII, figs. 65 and 65*a*.

Small forms averaging between 25 and 30 mm. in long diameter, the largest specimen measuring about 35 mm. long. Test elliptical to circular, depressed, not markedly thin at the margins.

Ambulacra not standing in relief, broad, wide open at the ends, pores continuing to the margin. Inner row of rounded pores diverging gradually to the margin, drawing together only very slightly at about two-thirds of the distance. The outer pore rows at first diverge strongly but draw together again sharply at the point where the inner rows tend to converge. At this point they change their form from elongated to rounded and continue to the margin nearly parallel with the inner rows. The plates of the ambulacral areas increase slowly in size from the apical shield to the margin, the increase being most rapid at the point where the pore rows draw together. Near the margins the pores stand about half-way between the inner and outer ends of the plates.

Anus marginal to inframarginal. Tubercles nearly the same size on the upper and lower sides of the test.

Very few specimens have been obtained which show the lower surface, and the writer has been unable to determine the character of the ambulacral furrows. As this species is closely related to *Astrodapsis tumidus*, in which the furrows are clypeastroid, it is probable that they are much the same here and that the *Brewerianus* should be classed with, or near, *Clypeaster* rather than with *Echinarachnius*, as heretofore.

Common in the Contra Costa County Miocene.

Genus **Astrodapsis** *Conrad*

Astrodapsis tumidus *Rémond*

PLATE XXI, FIG. 3

Astrodapsis tumidus RÉMOND., Proc. Cal. Acad. Sci., Vol. III, 1863–67, p. 52.
Astrodapsis tumidus. Figured by GABB., Geol. Surv. Cal., Palæontology, Vol. II, 1869, p. 37, Pl. XIII, figs. 68 and 68*a*.

Specimens ranging up to 45 mm. in diameter, average between 30 and 35 mm. Test circular to elliptical, depressed; margins, particularly in old individuals, inclined to be thickened and rounded, usually notched at the ends of the ambulacral areas.

Ambulacra always more or less elevated and showing, on perfectly preserved specimens, a faint groove running from the marginal notch more than half-way up to the apical system. Petals wide open at the ends, pores continuing almost to the margins. Inner rows of rounded pores only slightly convergent near the margin. Elongated pores of outer rows converging near the margin, becoming rounded and running parallel with the inner rows from that point.

Anus marginal or inframarginal. On well preserved specimens the inferior surface shows well marked, straight, undivided ambulacral grooves, which pass into the marginal notches and extend themselves on the upper surface, forming the median groove of the ambulacral areas. The tubercles are not noticeably different in size on the upper and lower surfaces.

The internal skeleton consists of a pair of strong, radially placed plates, extending half the distance from the margin to the center in each interambulacral space.

San Pablo formation, excepting the lowest beds.

Astrodapsis Whitneyi *Rémond*

PLATE XXI, FIGS. 4 AND 4*a*

Astrodapsis Whitneyi RÉMOND., Proc. Cal. Acad. Sci., Vol. III, 1863–67, p. 52.
Astrodapsis Whitneyi. Figured by GABB., Geol. Surv. Cal., Palæontology, Vol. II, 1869, p. 37, Pl. XIII, figs. 67 and 67*a*.

The average specimens of this species are considerably larger than those of *A. tumidus*. The largest specimen examined measured between 60 and 65 mm. in diameter. Test circular, strongly arched above; margin thin; marginal notches at the ends of the ambulacra deep.

Petals considerably elevated, with median groove running from the marginal notch toward the apex, pores similar in form and arrangement to those of *A. tumidus*.

Ambulacral furrows of the inferior surface well marked, straight, undivided. Anus inframarginal. Tubercles not differing materially on the upper and lower surfaces of the test, frequently smaller than in *tumidus*.

San Pablo formation, probably in the upper beds.

Genus **Scutella** *Lamarck*

Scutella Gabbi *Rémond*

PLATE XXII, FIGS. 5 AND 5*a*

Clypeaster Gabbi RÉMOND., Proc., Cal. Acad. Sci., Vol. III, 1863–67, p. 53.
Clypeaster Gabbi. Figured by GABB., Geol. Surv. Cal., Palæontology, Vol. II, 1869, p. 36, Pl. XII, figs. 64 and 64*a*.

Test circular, much depressed, margin thin. Average specimens 25 to 30 mm. in diameter, largest specimens ranging up to 40 and 45 mm. in diameter.

Petals short, not extending more than two-thirds of the distance to the margin; excepting the anterior one, they are nearly closed at the ends. Anterior petal wide open. Excepting in the anterior area, the ambulacral plates suddenly enlarge and the area rapidly widens beyond the ends of the petals. In these areas, pairs of small, round pores, diverging strongly from the ends of the petals, may be present almost to the margins. In the anterior petal the plates do not enlarge as noticeably toward the margin as in the others, neither do the more persistent pore pairs diverge as much.

Apical shield with four genital pores, there being none at the end of the posterior interambulacral area. Anus marginal to supramarginal; in quite a number of specimens it is found to be entirely on the upper surface. No marked difference is noticeable between the tubercles of the upper and lower surfaces.

The ambulacral furrows of the actinal surface are not usually well preserved and have been clearly seen on only a few specimens; they divide dichotomously a little less than half-way to the margin.

San Pablo formation, in the lowest beds.

Scutella interlineata *Stimpson*

PLATE XXII, FIG. 6

Scutella interlineata STIMPSON, Pacific R. R. Rep., Vol. V, 1856, p. 153, Pl. IV. fig. 30.
Scutella interlineata. Redescribed by RÉMOND., Proc. Cal. Acad. Sci., Vol. III, 1863–67, p. 14.

Test pentagonal to circular, angular or truncated posteriorly, somewhat arched above; summit nearly central and in front of the eccentric apical system, specimens ranging up to over 120 mm. in diameter.

Ambulacra rather broad, of unequal length, anterior three of about the same length and longer than the posterior pair. Anterior petal open at the end, the others nearly closed. Few if any pores continuing beyond the ends of the petals.

The distance from the eccentric apical system to the posterior margin is to the distance to the anterior margin as 1 to 1.5. The anus is supramarginal, being separated from the margin in adult specimens by about the width of one of the marginal interambulacral plates.

No specimens have been seen by the writer in which the ambulacral furrows are well shown. On such specimens as show the lower side, the furrows seem to be dichotomously divided near the mouth. This agrees with Rémond's description, which also states that the furrows are not as well marked nor as much branched as in *Echinarachnius excentricus.*

The spines of the upper surface are about 1 mm. long; they are longitudinally striated and at the distal end are strongly swollen and obliquely truncated or bent. The spines of the lower surface are slender striated rods about 2 to 3 mm. long. The tubercles differ little in size on the upper and lower surfaces.

The internal skeleton comprises numerous irregular pillars and plates near the margin and a pair of radial plates in each interambulacral space.

Common in the Merced series.

Genus **Echinarachnius** *Leske*

Echinarachnius Gibbsi *Rémond*

Plate XXII, Fig. 7

Scutella Gibbsi Rémond, Proc. Cal. Acad. Sci., Vol. III, 1863–67, p. 13.
Scutella Gibbsi. Figured by Gabb, Geol. Surv. Cal., Palæontology, Vol. II, 1869, p. 37, Pl. XII, figs. 66 and 66*a*.

Test quadrate-oval in outline. Upper surface well arched, summit behind the middle of the long diameter but in front of the very eccentric apical system. Specimens ranging up to 70 mm. in length.

Petals broad, open at the ends. Posterior laterals wide apart, ovate in outline, one-half the length of the anterior pair. Anterior petal longer than the anterior laterals; scattered pores continue some distance beyond the end.

The apical shield is very eccentric. In a specimen measuring 52 mm. in length, the distance from the apical shield to the posterior margin is to that to the anterior margin as 1 to 2.18; in a specimen 70 mm. long the ratio is 1 to 2.89. Four genital pores are present. The madreporic body is large and is pentagonal in outline. The anus is inframarginal.

The well marked ambulacral furrows are dichotomously branched near the mouth-opening and send off numerous secondary branches from these forks. The numerous tubercles of the upper surface are very small and are set in faint pits. On the lower surface the tubercles are fewer in number and larger, and stand in well defined pits.

From Neocene beds near Buena Vista Lake, Kern County, and listed by Ashley[4] from his transition beds near Santa Cruz.

Echinarachnius excentricus *Eschscholtz*

PLATE XXII, FIG. 8

Scutella excentrica ESCHSCHOLTZ, Zool. Atl., Pl. XX, fig. 2, 1826.
Echinarachnius excentricus VALENCIENNES, Voyage Vénus, Pl. X, 1846.

Though a discussion of this species is perhaps not properly included in a treatise on Tertiary forms, its doubtful occurrence in the Pliocene is considered a warrant for its introduction. Moreover, the position the species occupies as the last of the Clypeastroids in this region makes desirable a comparison with the extinct forms. This is graphically done on Plate XXII, where *E. excentricus* appears with its nearest allies from this Coast.

From *E. Gibbsi* the *excentricus* differs in the less degree of eccentricity of the apical system and in the greater complexity and length of the ambulacral furrows. The distance of the apical shield from the posterior margin is to that from the anterior margin as 1 to 1.8+. The ambulacral furrows are split up into a great number of small branches, of which the strongest pass over the margins and extend over the upper surface. Four of the strongest furrows run to the lateral petals and stretch through their median areas almost to the apical system. Those furrows not passing to the petals sometimes reach half-way to the apical system.

Quaternary, possibly also in the later Pliocene. The fossil forms do not differ materially from those of the Recent period.

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BERKELEY, CALIFORNIA
September, 1898

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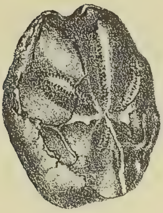
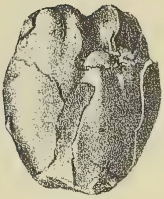
[4] Proc. Cal. Acad. Sci., 2d Ser., Vol. V, p. 328.



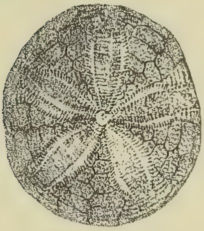
1.

Schizaster Le Contei, sp. nov. View of an obliquely crushed specimen from above



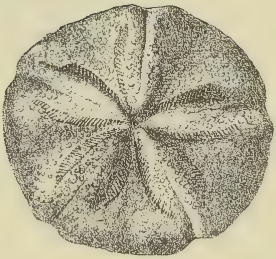
1a

Lower surface of the specimen of *Schizaster Le Contei* shown in fig. 1



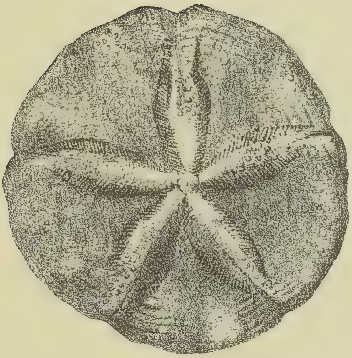
2.

Clypeaster (?) *Brewerianus* RÉMOND



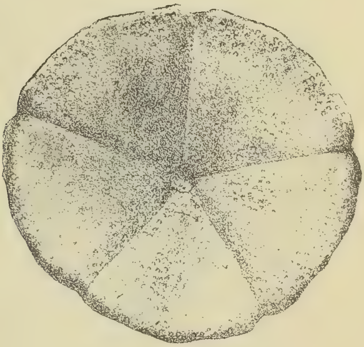
3.

Astrodapsis tumidus RÉMOND



4.

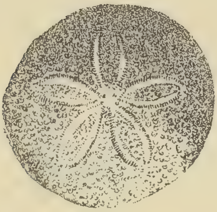
Astrodapsis Whitneyi RÉMOND



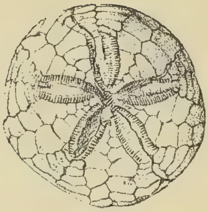
4a

Lower surface of the specimen of *Astrodapsis Whitneyi* shown in fig. 4

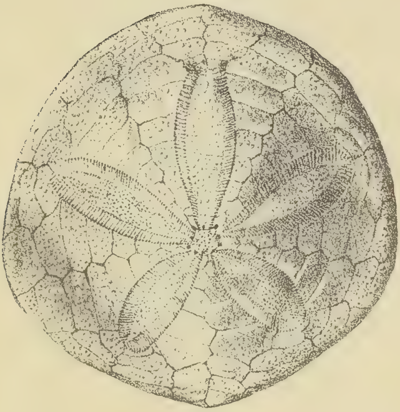
All figures natural size



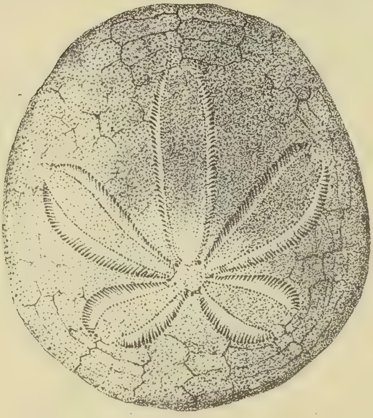
5.
Scutella Gabbi Rémond



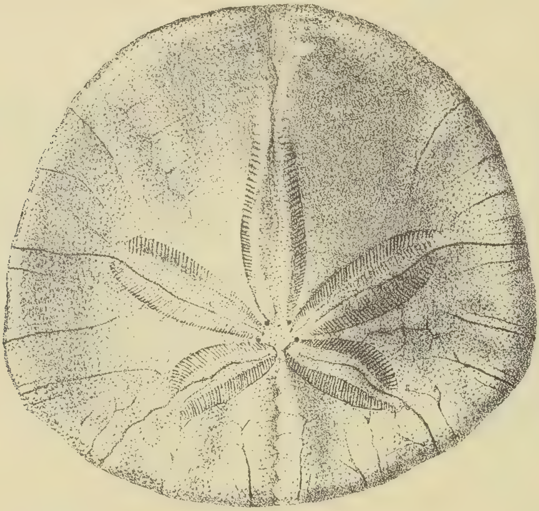
5a
Scutella Gabbi Rémond. Showing form and arrangement of plates and pores



6
Scutella interlineata Stimpson



7
Echinarachnius Gibbsi Rémond



8
Echinarachnius excentricus Eschscholtz

All figures natural size

THE FAUNA OF THE SOOKE BEDS OF VANCOUVER ISLAND

THE Sooke beds, so named from their occurrence in the Sooke district, on the southern coast of Vancouver Island, have been principally studied in the field by Dr. C. F. Newcombe of Victoria, B. C., the fossil invertebrates collected by him being placed at the disposal of the writer for study and description. As the result of the investigation of this material, together with that from other horizons, the author has, during the past two years, published two diagnostic notes[1] on this fauna.

As no figures of the new species have been published, and an investigation of this fauna is not easily combined with any other to which the writer is at present giving particular attention, it was thought best to bring together in one note the principal facts known regarding the fauna, furnishing also figures of the new species. Future investigation will probably add many new forms to the list given in this paper.

The first mention of the Sooke beds made in the literature is by Mr. James Richardson,[2] who in 1876 noticed the occurrence of fossiliferous rocks in the Sooke district. The following extract from his paper expresses his opinion of the beds:—

"At the mouth of John's River the lowest beds are gray sandstone, in some places crowded with fossils belonging apparently to three or four species. These are referable to the genera *Ostrea*, *Pecten*, and *Saxidomus*, and are either of Tertiary or Post-Tertiary age."

In 1892 Dr. W. H. Dall[3] mentioned the occurrence of marine beds of Miocene age near Sooke.

Dr. Newcombe has, in 1893–98, made numerous visits to the out-

Proceedings of the California Academy of Sciences, ser. 3, Geology, vol. 1, no. 6, pp. 175–180, pl. XXIII, March 6, 1899.

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[1] "Note on Two Tertiary Faunas from the Rocks of the Southern Coast of Vancouver Island," Bull. Dep't Geol., Univ. Cal., Vol. II, No. 3, Dec. 1896.

"New Species of Tertiary Mollusca from Vancouver Island." Nautilus, Vol. XI, October, 1897, p. 64.

[2] Geol. Surv. Canada, Rept. Prog., 1876–77, pp. 160–192.

[3] Bull. U. S. Geol. Surv., No. 84, p. 230.

croppings of the beds near Muir and Coal Creeks, bringing back a considerable amount of material in a very good state of preservation.

The cliffs in which the fossils occur are said by Dr. Newcombe to consist of soft sandstone and conglomerate. The strata do not appear to be greatly disturbed. Molluscan remains are found in abundance in both the sandstone and the conglomerate. In most instances the specimens are well preserved, showing the original unchanged material of the shell.

The number of known species being small, it is perhaps not possible to determine with absolute accuracy the age of this horizon. The recent and extinct species are, however, about evenly divided, so that both the Quaternary and the Eocene are beyond the range of possibility. Within the limits of the Neocene the nearly equal

TABLE ILLUSTRATING THE RELATIONSHIPS OF THE SOOKE FAUNA

	Recent	Plio-cene, Calif.	Mio-cene, Calif.	Astoria Mio-cene[4]	Extinct
1. *Placunanomia macroschisma* DESH.	*	*			
2. *Mytilus edulis* LINN.	*	*	*	*	
3. *Cerithidea Californica* HALD.	*	*	*		
4. *Acmæa mitra* ESCH.	*				
5. *Crepidula rugosa* NUTT. (*aff.*)	*				
6. *Pecten æquisulcatus* CARP. (*conf.*)	*				
7. *Pecten hastatus* SOWB. (*conf.*)	*	*	*		
8. *Chrysodomus dirus* REEVE	*				
9. *Yoldia impressa* CON.	*	*	*	*	
10. *Pectunculus patulus* CON.		*	*	*	*
11. *Trochita inornata* GABB.			*	*	*
12. *Sinum scopulosum* CON. (*conf.*)				*	*
13. *Cytherea* (?) *Newcombei* MERRIAM					*
14. *Cytherea Vancouverensis* MERRIAM					*
15. *Patella geometrica* MERRIAM					*
16. *Nassa Newcombei* MERRIAM					*
17. *Bullia buccinoides* MERRIAM					*
18. *Fusus* sp. nov.					*
19. *Fusus* sp. nov.					*
20. *Bittium* sp. nov. (?)					*
21. *Crepidula* sp.					
22. *Ostrea* sp.					
23. *Cardium* sp.					
24. *Cerithidea* sp.					
25. *Tapes* (?) sp.					

---

[4] Referring to the fauna described by Conrad from Astoria and identified by the writer at Carmanah Point, Vancouver Isl. See Bull. Dep't Geol., Univ. Cal., Vol. II, No. 3, p. 102.

number of extinct and living forms points to Middle Neocene, while the general relationships of the fauna to the known Miocene and Pliocene faunas of the coast show no preponderance of affinity in either direction. The total evidence available seems then to indicate the Middle Neocene age of the Sooke fauna.

The following species which have previously been diagnosed by the writer are here redescribed and figured:

Genus **Cytherea** *Lamarck*

Cytherea (?) Newcombei *Merriam*

PLATE XXIII, FIGS. 1 AND 1*a*

Cytherea, sp. nov., Bull. Dep't. Geol., Univ. Cal., Vol. II, No. 3, p. 106.
Cytherea Newcombei MERRIAM, Nautilus, Vol. XI, 1897, p. 64.

Shell subquadrate to oval, high, moderately thick, truncated anteriorly. Beaks not prominent. Lunule faintly marked. Surface ornamented with numerous, irregularly placed growth lines and ridges. On some well preserved specimens a large number of very faint, radial lines are visible. Length of large specimens 70 mm., breadth 55 mm. Hinge of right valve with three cardinal teeth and a short pit for the anterior lateral tooth of the opposite valve. This pit for the reception of the anterior lateral tooth is shallower and much shorter than in the following species.

Cytherea Vancouverensis *Merriam*

PLATE XXIII, FIG. 2

Cytherea, sp. nov., Bull. Dep't. Geol., Univ. Cal., Vol. II, No. 3, p. 106.
Cytherea Vancouverensis MERRIAM, Nautilus, Vol. XI, 1897, p. 64.

Shell oval, narrowly rounded anteriorly. Beaks prominent. Lunule well marked. The somewhat weathered surface of the shells ornamented by numerous, irregularly-placed growth ridges. Length of type specimen 62 (?) mm., breadth 48 mm. Hinge of right valve with three cardinal teeth and a long, deep tooth-pit for the reception of the anterior lateral tooth of the left valve. Pit between the two anterior cardinal teeth of the right valve ordinarily narrower and deeper than in *C. Newcombei.*

Genus **Patella** *Linné*

Patella geometrica *Merriam*

PLATE XXIII, FIG. 4

Patelloid, sp. nov., Bull. Dep't. Geol., Univ. Cal., Vol. II, No. 3, p. 106.
Patella geometrica MERRIAM, Nautilus, Vol. XI, 1897, p. 65.

Shell large and heavy, up to 50 mm. or more in length, suborbicular. Apex elevated, well forward. Surface ornamented by about twenty broad, strong, radial ribs, which are much wider than the interspaces. Radial ribs crossed by numerous prominent, narrow, sometimes leafy, transverse ridges.

Genus **Nassa** *Martini*

Nassa Newcombei *Merriam*

Plate XXIII, Fig. 3

Nassa, sp. nov., Bull. Dep't. Geol., Univ. Cal., Vol. II, No. 3, p. 106.
Nassa Newcombei Merriam, Nautilus. Vol. XI, 1897, p. 65.

Shell between 25 and 30 mm. in length. Whorls five, with a well marked shoulder, ornamented by numerous longitudinal and transverse ribs which give the middle portion of the whorls a tessellated appearance. The upper revolving rib, which forms the angle of the shoulder, is stronger than the others and is usually separated from them by a distinct groove. On the last whorl the transverse ribs (about 25) are dominant on the upper portion, excepting the shoulder, and are latticed by the less conspicuous revolving sculpture. On the lower portion of the whorl the transverse ribs disappear leaving the well defined revolving ribs uninterrupted.

Genus **Bullia** *Gray*

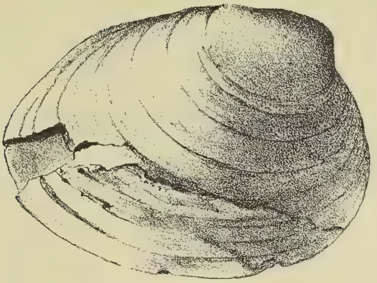
Bullia buccinoides *Merriam*

Plate XXIII, Fig. 5

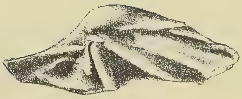
Ancillaria, sp. nov., Bull. Dep't. Geol., Univ. Cal., Vol. II, No. 3, p. 106.
Bullia buccinoides Merriam, Nautilus, Vol. XI, 1897, p. 65.

Shell ovate, whorls five. Spire short. Suture partially or entirely covered. Aperture with strong anterior notch. Outer lip thin, sharp; inner lip with broad callus. Length 25–30 mm.

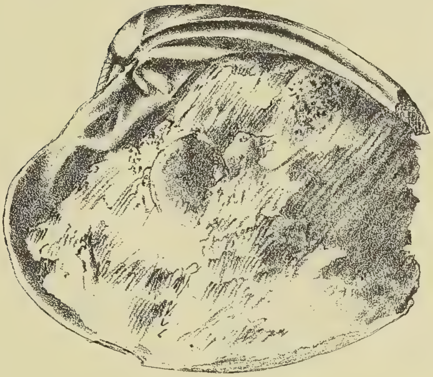
Palæontological Laboratory
University of California
Berkeley, California
September, 1898



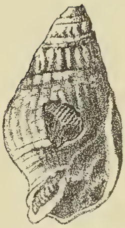
1
Cytherea (?) *Newcombei* MERRIAM



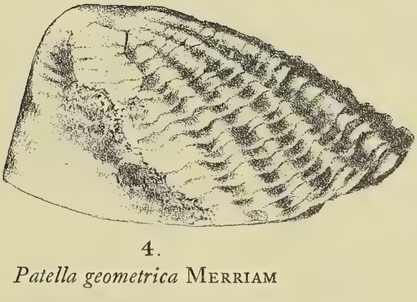
1a
Doubtful hinge of right valve of
Cytherea (?) *Newcombei*



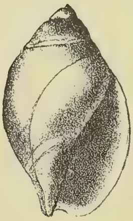
2.
Cytherea Vancouverensis MERRIAM



3
Nassa Newcombei MERRIAM



4.
Patella geometrica MERRIAM



5
Bullia buccinoides MERRIAM

All figures natural size

A NOTE ON THE FAUNA OF THE LOWER MIOCENE IN CALIFORNIA

In nearly all typical sections of the Californian Miocene it is possible to distinguish at least two divisions of the system based on the geological range of faunas. At least three faunal zones can be recognized in Contra Costa County, if we include the variation in fauna due to change in the character of the sea bottom during the deposition of the Monterey shale. This does not mean that there are only two divisions possible, or that the two mentioned are the same two in different sections, but rather that we are certainly dealing with more than one distinct zone.

One of the most characteristic phases of the Miocene in California is the Monterey shale. The fauna of this formation, as we know it, is limited to foraminifera, radiolaria, fish, cetaceans, a crustacean and a few mollusca. Among the last, *Pecten peckhami*, the indefinite *Tellina congesta* and a *Leda* are the most common forms. The fauna belongs to a deep water facies and must not be confused with the faunas of sandy, shallow water deposits. At many places where sandstone is interstratified with the shales a very sudden change of the fauna is noticed, nearly all of the typical shale species dropping out but reappearing in shaly layers above.

In addition to the shale fauna, there are in Contra Costa County two faunal zones in the Miocene, one above and one below the shale. The upper division has its nearest affinities with the San Pablo, from which it can be distinguished by the presence of *Clypeaster* (*?*) *brewerianus*, *Trochita costellata*, several new species of *Modiola*, and other forms.

The fauna of the lower division is much more characteristic than the upper: that is to say, it differs more decidedly from that of the beds immediately above and below it. This fauna includes the following forms:

University of California Publications, Bulletin of the Department of Geology, vol. 3, no. 16, pp. 377–381, March 1904.

Agasoma gravida Gabb.
Chrysodomus n. sp.
Ficula n. sp.
Olivella pedroana Conrad.
Neverita near *callosa* Gabb.
Turritella indet.
Crepidula indet.
Dosinia mathewsoni Gabb.
Chione mathewsoni Gabb.
Mytilus mathewsoni Gabb.
Venus n. sp.
Glycimeris near *generosa* Gould.
Leda taphria Dall.
Nucula divaricata Hinds.
Arca n. sp.

The most characteristic species are *Agasoma gravida*, *Dosinia mathewsoni*, *Chione mathewsoni*, and *Mytilus mathewsoni*. These beds rest upon the Tejon, which is very fossiliferous only a few yards below the contact. A large percentage of the species in this horizon do not appear in the upper Miocene and as yet not a single species has been found to extend down into the Tejon. In Contra Costa County the fauna of this zone is more distinctive than that of the Monterey shale, considering even that the latter represents a deep water facies.

The lower fauna is recognized at many places in Contra Costa County, and always next the base of the series. This faunal division might appropriately be called the zone of *Agasoma gravida*. Forms like *A. gravida* have a wide geographic range on this Coast and are apparently characteristic of the base of the Miocene.

South of Contra Costa County the deposits in the middle Tertiary appear to take on quite a different character. Instead of a thin bed of sandstone below the Monterey shale, very considerable thicknesses of heavy sandstone and clay may form the basal beds. These may swell out to make a much more important stratigraphic unit than the basal sandstone of the Contra Costa region. In the Pacific Railroad survey reports, heavy fossiliferous sandstones are mentioned by Antisell[1] as occurring at the base of the Miocene. Later, Whitney[2] presented sections of several regions where extensive Miocene sandstones lie below the shale. In the palaeontology of Whitney's report, Gabb[3] refers to the shale as the upper member of the Miocene, evidently having in mind the sandstones below it. In several of these references *Turritella ocoyana* is mentioned as a common form in these beds.

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[1] T. Antisell. Pacific R. R. Rep. Vol. 7, p. 197.

[2] J. D. Whitney. Geol. Surv. Calif. Vol. I, p. 128, fig. 10, and p. 135, fig. 17.

In 1895, Ashley[4] described a thick series of sediments which he supposed to rest conformably below the Monterey. He listed several species from it, of which the most important and characteristic is *Turritella hoffmani.* Ashley was uncertain about the age of these beds, thinking they might be partly Eocene.

In 1896, Fairbanks,[5] in his discussion of the geology of Point Sal, described extensive Miocene beds of clay and sandstone below the shale. Still more recently in his work on the San Luis Obispo Quadrangle he has carefully worked out the relation of this horizon to the shale and made extensive collections in it. These collections were turned over to the University of California. They were worked over by Mr. F. C. Calkins, who has found in them a very interesting fauna. *Turritella hoffmani* is perhaps the most characteristic species. Along with it are a great many forms not known in the later beds. Other collections made more recently by Dr. Ralph Arnold in the *T. hoffmani* beds described by Ashley show the same fauna as that collected by Fairbanks almost species for species.

Search has been made in this fauna for species like those of the lowest Miocene of Contra Costa County. So far there have been found an *Agasoma* very much like *gravida*, a *Dosinia* of the type of *mathewsoni* and a *Chione* of the type of *mathewsoni*. The *Dosinia* and *Chione* are not identical in form with the types but come near them. This fauna probably belongs to the *Agasoma* zone of the lower Miocene, and were it not for certain complications that arise it might be designated as such. For the present it may be called the zone of *Turritella hoffmani.*

The complications just mentioned are due to the fact that in many of the regions in the southern part of the state, where the sandstone phase of the Miocene is developed extensively below the shale, the fauna containing *T. hoffmani* is not discovered, but in its place there is found an abundance of *Turritella ocoyana* along with *T. variata.* In most of the localities only a few species have been found with those two forms, but enough has been seen to make it appear that this is not exactly the same zone as that of *T. hoffmani.* On the other hand, there is evidence enough to show that the two horizons are not far removed from each other. Near Bakersfield, in the beds from which the type of *T. ocoyana* was obtained, an extensive fauna has been discovered. Most prominent among the species are three forms of *Agasoma*, the most common of which is near *gravida.* In some respects it is intermediate between *A. gravida* of the lower Miocene and *A. sinuata* of the upper Miocene.

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[3] W. M. Gabb. Geol. Surv. Calif., Palaeontology. Vol. II, p. 59.

[4] G. H. Ashley. Leland Stanford Junior Publications. Geol. and Palaeont. No. 1, p. 291.

[5] H. W. Fairbanks. Bull. Dept. Geol. Univ. Calif. Vol. II, No. 1, p. 5.

Both the zone of *T. hoffmani* and that of *T. ocoyana* appear to belong close to the *Agasoma* zone of Contra Costa County. It is also probable that the *T. hoffmani* zone is the older of the two, as its fauna is made up very largely of extinct forms. That of the *T. ocoyana* beds at Kern river contains a much larger number of recent species, it is generally more modern in its appearance, and it also shows the *Agasoma* group much more highly developed and much more common than in the *T. hoffmani* beds.

In the southern part of the state we probably have two fairly distinct zones of the lower Miocene. The question naturally arises; are we to consider the beds in Contra Costa County as the equivalent of one or both of these divisions? This much may be said, viz.: The fauna of the *Agasoma* beds of Contra Costa County seems to contain a somewhat larger number of recent species than the *T. hoffmani* division and also lacks some of the extinct species which belong to it. That this is probably not simply a geographic variation in the fauna is shown by the proximity of the *T. hoffmani* beds of Ashley to the *Agasoma* beds of Contra Costa County.

When we come to study the subdivisions of the lower Miocene both palaeontologically and stratigraphically some interesting things relating to the movement of the Miocene shore lines are suggested. The *T. hoffmani* zone is found principally in the western or coast region. The *T. ocoyana* zone occurs in the western region and also to the east of the great valley, where the *T. hoff-*

mani is not yet known. It would therefore appear that the sea had not reached as far east in the earliest Miocene as it did later, and that the thick shale beds over the lower sands of the western region were formed while sandy *T. ocoyana* beds were being deposited to the east.

University of California
March, 1904

GENERAL PALÆONTOLOGY

AN OUTLINE OF PROGRESS IN PALAEONTOLOGICAL RESEARCH ON THE PACIFIC COAST

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History of vertebrate palaeontology....................1701
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Conclusions....................1708
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INTRODUCTION

THE earliest published record known to the writer giving data on palaeontological material from the West Coast section of North America appears to be included in Beechey's report on the voyage of H.M.S. "Blossom," published in 1831. In this publication Professor Buckland gives a description of the geology in the region adjacent to San Francisco Bay, and notes that, in 1827, "Petrified bones of a cylindrical form" were found in a cliff of sand or loose sandstone near Santa Cruz. These remains probably pertained to some member of the cetacean order which is largely represented on the West Coast, and is still, at this late date, among the groups of which the Pacific Coast history is practically unknown.

Development of the study of history of life on the western border of North America virtually began with investigation of collections obtained by the Wilkes Expedition or the United States Exploring Expedition, and by the United States Government survey parties engaged in preliminary work for the purpose of determining possible transcontinental travel routes between the Mississippi River and the Pacific Ocean. Collections of molluscan remains obtained in the period of these surveys were described by T. A. Conrad in the American Journal of Science in 1848, in the U. S. Exploring Expedition Report in 1849, and in the volumes of the Pacific Railroad Survey of 1855 to 1857. This work was followed in the early sixties by

Annual address of the President, read before the Palaeontological Society, Pittsburgh, Pa., December 31, 1917. *University of California Publications*, *Bulletin of the Department of Geology*, vol. 12, no. 3, pp. 237–266, August 6, 1921.

that of W. M. Gabb in connection with the second California State Geological Survey. The pioneer studies of Conrad, Gabb, and others brought together a wealth of information on the history of invertebrates on the Pacific Coast, outlined the main features of the palaeontology of this region, and laid the foundation for future detailed work. Also near this period occurred the earliest important investigations of extinct vertebrate faunas in the territory west of the Wasatch, begun in 1865 by J. Leidy, and followed by O. C. Marsh on specimens obtained from the John Day region of Oregon by Thomas Condon, who was the first to recognize the significance of the fossil mammal faunas in eastern Oregon. In nearly the same period the first studies in West Coast palaeobotany were begun by Leo Lesquereux.

For approximately a quarter of a century following the period ending with the termination of the State Geological Survey of California in 1867, relatively little advance was made in palaeontological study on the western side of the continent. This stage of stagnation extended up to the time of initiation of palaeontological investigations at Stanford University and the University of California in 1892 to 1894, and has been followed by an epoch of continuous expansion in many directions through the work of faculty and students of the two universities, and by alumni who have continued their progress in scientific or technical work.

The history of palaeontological research in the Pacific Coast region, up to the present time, seems then clearly divided into two well marked periods. The first stage includes the pioneer work of Conrad, Gabb, Marsh, Cope, Lesquereux, and others. Following an interruption of about twenty-five years extending over the seventies and eighties, the second stage begins with the inauguration of work at the two universities of California, and continues with constantly increasing emphasis up to the present year.

Although the palaeontological studies of vertebrates, invertebrates, and plants have the same fundamental significance with relation to the great problems of biological history, and though all may ultimately have similar bearing upon questions of time classification and correlation, it is true that the history of these three groups has been worked out on the West Coast with rather distinct original aims and in different regions. These fields may therefore be considered separately.

History of Invertebrate Palaeontology

To T. A. Conrad, of the Philadelphia Academy of Sciences, belongs, unquestionably, the credit of pioneering invertebrate palaeontological work on the West Coast. His descriptions of the faunas obtained from Tertiary beds near the mouth of the Columbia River give us the first discussion of a marine fauna on this side of the continent, and offer the first correlation of a West Coast fauna with that of a region outside the Pacific area. Conrad correlated the fossils from Astoria with Miocene types of the Atlantic Coast of the United States, and also with faunas of the Miocene of Great Britain. Although various modifications of this correlation have been made in later years, through use of larger and better collections, and in adjustment to a more thoroughly worked out modern classification, the studies of Conrad still hold as a good pattern for pioneer investigations, prosecuted as they were under conditions vastly different from those controlling the work of students of the present day.

Conrad's papers on the Tertiary of California, published in the Pacific Railroad surveys, beginning with the discussion of the Eocene of Canada de las Uvas and the Miocene of Ocoya Creek, in volume 5 of these reports, give us again an excellent form of preliminary work, in which the determinations of age and descriptions of species are as satisfactorily done as one could expect under the conditions. His studies were continued in volumes 6 and 7, through description of faunas ranging rather widely over the Tertiary.

With the inauguration of the second Geological Survey of California in 1861, under the direction of J. D. Whitney, palaeontological study of the West Coast faunas was given an unusually important place. It is evident that Whitney realized the necessity for careful studies of this nature, in order to make possible necessary correlation over the California region, and to permit comparison between the Pacific Coast province and other areas of the world. The absence of adequate maps prevented extensive use of stratigraphic criteria, and it was clear that progress in geological study of the sedimentary formations of California would be impossible without full data concerning the palaeontological sequence of typical sections. Whitney's view of this question seems to be expressed by his inclusion of two volumes of palaeontology in the three representing his Report of the Geological Survey of California. In a later volume, on the Auriferous Gravels of California, published by Whitney, considerable emphasis is again placed upon the palaeontological aspect of the work.

The first volume of the Palaeontology of California, published in 1864, included a study of the Carboniferous and the Jurassic, by F. B. Meek, and a description of Triassic, Cretaceous, and Eocene faunas, by W. M. Gabb. Considering that this work was of the pioneer type and executed within the three years following the beginning of the survey, we must grant that it was a most excellent contribution to the faunal study of North America. Volume 2, published in 1869, is another very important contribution, representing entirely the work of Gabb, and including a wide range of faunas from the Cretaceous to the later Cenozoic. Barring the unfortunate confusion of the Cretaceous and the earlier Eocene, the work of Gabb must be considered as a model, upon which improvements in method and form have scarcely been made in later publications originating in this region.

The conclusion of the State Geological Survey work, under the hand of Gabb, furnished for the California region an excellent palaeontological series, beginning with a somewhat scanty fauna of the Carboniferous and ranging through to the Pleistocene. To many it appeared that the invertebrate series of California had already been rounded out, and that later studies, though shifting lines here and there, would not greatly alter the fundamental conclusions reached by Gabb and Whitney. This publication, taken with the earlier studies of Conrad, did undoubtedly furnish the major outlines of palaeontological sequence for invertebrate faunas. Later studies have shown that lines may be moved slightly up or down; that generic and specific descriptions may be modified; that biological and geological classifications must be altered through further subdivision; and that significant additions must be made. I believe, however, that too great praise cannot be given to the students of this pioneer period for the large measure of result coming from comparatively few years of work, under conditions much less favorable than those now obtaining, and with knowledge of general palaeontological problems very much less advanced than at the present moment.

Between the period marking the conclusion of work of the second Geological Survey of California and the initiation of palaeontological work at the California universities, a number of significant palaeontological studies relating to the invertebrate faunas of the West Coast were published. Belonging to this intermediate stage is the important work of C. A. White, who devoted special attention to the Cretaceous problem of California and made valuable additions to knowledge in bulletins of the United States Geological Survey. Important reviews of the California faunas in this period are the United States Geological Survey bulletins on the Eocene, by W. B. Clark, and on the Miocene, by W. H. Dall. Also having its inception in this period is the beginning work of T. W. Stanton, of the United States Geological Survey, resulting in the publication of important papers falling within the limits of the next period. Among the papers by Dr. Stanton, special mention is to be made of his study of the fauna of the Knoxville Cretaceous, published in 1895, and of an important paper on the fauna of the Shasta and Chico formations, published in the bulletins of the Geological Society of America in 1893.

In the latter part of the intermediate stage comes also the very significant study of Alpheus Hyatt on the Jurassic and Triassic of California, presented in two papers in bulletins of the Geological Society of America in 1892 and 1894. In these contributions a number of new forms were described and valuable evidence concerning the relationship of these faunas was presented.

Toward the end of this intermediate period, determinations of faunas of Cretaceous and Tertiary age were made for bulletins of the California State Mining Bureau by J. G. Cooper, formerly associated with the State Geological Survey. Dr. Cooper also described and figured a number of new species, including both marine and fresh-water types.

The second period of active investigation of invertebrate palaeontology on this coast began with the work of James Perrin Smith on faunas of the older sedimentaries, including the Jurassic, Triassic, and Carboniferous in regions bordering the Sierra. Papers by Professor Smith, in the bulletins of the United States Geological Survey and the Journal of Geology, made important contributions to assembled information on the age of the auriferous slates of the Sierra Nevada, and added to our knowledge of the Jurassic and Triassic faunas. Following the discovery of a most extraordinary section of early Mesozoic rocks in Shasta County, California, by

H. W. Fairbanks, and the recognition of the unusually well-preserved Triassic remains in this section, Professor Smith began an epoch-making series of studies on the West American Triassic. This investigation, initiated in studies of the upper division of the Triassic of northern California, was extended to the middle and lower Triassic of Nevada and Idaho. The results of these researches have given us a monumental work covering the most significant series of Triassic deposits of the Western Hemisphere, and have also given us one of the most important contributions to our knowledge of the Triassic faunas and of the early Mesozoic Cephalopoda in the whole field of palaeontological literature.

Following the studies of Professor Smith on the earlier rocks of the California section came the work of G. H. Ashley of Stanford University on the Tertiary faunas, and that of Ralph Arnold of Stanford University on the Pleistocene of the San Pedro region. Arnold's study of the Pleistocene, beginning with the first assembling of material by Delos Arnold, made a very significant addition to our knowledge of the latest faunas of the Cenozoic, and furnished the basis for study of the whole marine Pleistocene of the Pacific Coast region. Arnold's study of the Pleistocene fauna was followed at Stanford University and later on in the Geological Survey by investigations covering especially the middle and later Tertiary of southern California. Arnold's paper on the Tertiary and Quaternary Pectens of California represents the most important study of a group of Tertiary invertebrates on the West Coast published up to the present time. Numerous papers by Arnold, appearing mainly in the bulletins of the United States Geological Survey, and representing the results of excellent work on the oil producing formations of California, include studies of the Oligocene, lower, middle, and upper Miocene, the Pliocene, and the Pleistocene. These publications register a distinct advance in study of Tertiary faunal sequence and in our knowledge of the composition of the Tertiary faunas of the Pacific Coast. Certain papers by Arnold were in part published with the coöperation of George H. Eldridge, geologist of the Geological Survey, and later with Robert Anderson, of the Geological Survey.

Beginning with the second period and continuing up to the present time, important investigations were carried on by F. M. Anderson at Stanford University, University of California, as geologist with the Southern Pacific Company, through the California Academy of Sciences, and later as an independent investigator. Anderson's papers on the Cretaceous deposits of the Pacific Coast, published through the California Academy of Sciences in 1902, marked an advance in the development of our knowledge of this fauna on the West Coast. His papers on the faunas of the middle and later Tertiary, and covering important phases of this life on both eastern and western sides of the San Joaquin Valley, contributed much to our knowledge of Cenozoic invertebrate palaeontology. Later studies in coöperation with Bruce Martin added very significant data relative to this field.

A revision of the Eocene faunas of the California region was begun by R. E. Dickerson in 1909 and was continued without interruption up to 1917. This work began with the discovery of definite evidence of separation of the lower Eocene or Martinez fauna from the Chico Cretaceous and the later Eocene fauna represented in the Marysville Buttes. A monograph on the Martinez fauna added much to knowledge of this stage of the Eocene. Numerous shorter papers have been issued on various aspects of the Eocene of the whole Pacific Coast region, the work on later Eocene culminating in a review of the Tejon fauna. In the geologic sense one of the most important contributions of this work lies in the presentation of evidence of the Eocene age of the marine Ione beds. Dickerson's studies of the Eocene greatly increase this fauna, and give a better view of the geographical distribution of its various phases.

In 1913, E. L. Packard undertook a further study of the Cretaceous of the Pacific Coast, commencing with investigation of an interesting section in the Santa Ana Mountains of southern California. The work has added considerably to our knowledge of faunal range and geographical distribution of the late Cretaceous marine invertebrates of this coast.

Dr. Packard has also carried on an intensive investigation of the mactrine pelecypods of the West Coast begun under the direction of Professor C. E. Weaver at the University of Washington. This study has been one of the most difficult and most carefully conducted investigations of a group of fossil invertebrates accomplished on the Pacific Coast.

The Miocene, especially in its later phases in California, has been the subject of long-continued and intensive study by Bruce L. Clark, whose paper on the San Pablo fauna represents the most minute analysis of a Cenozoic fauna of the West Coast appearing since the publication of Arnold's monograph on the San Pedro Pleistocene. As yet no other palaeontological study in California has given us such detailed dissection of a stratigraphic sequence with such careful discussion of the significance of sequence. This work is being continued in the upper portion of the Miocene below the San Pablo. Dr. Clark has moreover made an exhaustive study of the Oligocene of middle California, and an extensive publication on this fauna is now in press. He has also carried out a study of the whole Oligocene fauna of the West Coast to be presented in monographic form in the near future.

The Pliocene faunal problem of California has been attacked by Bruce Martin, of the University of California, who explored widely over the West Coast, and has made two significant contributions through the University of California Publications: one, a description of new species, the other, a general faunal study of the Pliocene of middle and northern California, appearing in 1916. The work of W. A. English on the Fernando Pliocene near Newhall, and especially the recent studies of J. O. Nomland on the Jacalitos and Etchegoin of the Coast Range region have advanced our knowledge of the southern Pliocene considerably beyond the stage to which it was carried by the excellent work of Arnold and Anderson and F. M. Anderson. Nomland's analysis of the Etchegoin Pliocene fauna, and of the wonderful 10,000 foot section in which it is found, contributed much to understanding of the faunal composition of the Pliocene and of the faunal sequence.

The Pacific Coast Province has been assumed by the writer to be divisible into two major parts: the California Area and the Puget Area, the latter including the region of western Washington and Oregon. In the Puget region, study of invertebrate faunas is much less advanced than in the California Area, due largely to the smaller number of local investigations.

Following the early work of Conrad and others, comparatively little was done in the region of the northwest until the first decade of the present century in which we have an important reconnaissance paper by Ralph Arnold on the faunas of the Pacific Coast region of the Olympic Peninsula published in a bulletin of the Geological Society of America in 1905. In 1909 W. H. Dall published a large and very important study on the Miocene of Astoria and Coos Bay, Oregon, in which he reviewed all previous work, contributed largely to the middle Tertiary fauna, revised the determinations, and organized all of the much-scattered literature contributed up to that time. Dall's work was followed by the studies of C. E. Weaver at the University of Washington, Arnold and Hannibal, Bruce Martin, R. E. Dickerson, and others. Especially the recent papers of Weaver, published by the Geological Survey of Washington and by the University of Washington, and of Arnold and Hannibal, in the Proceedings of the American Philosophical Society, have opened up a wide and almost unknown field in invertebrate palaeontology of the northwest. Much still remains to be known of the composition, sequence, distribution, and age of the faunas of the Puget Area, and no field of invertebrate palaeontology of the West Coast may be expected to furnish larger contributions in the next decade.

With the exception of James Perrin Smith's papers on Triassic Cephalopoda, Ralph Arnold's monograph of the Tertiary and Quaternary Pectens of California, and Packard's investigation of the mactrine pelecypods, the greatest part of the work on West Coast invertebrate palaeontology has up to this time concerned itself largely with discussion of faunal sequence. In addition to the description of special groups already discussed, particular reference should be made to the work of W. S. W. Kew on the Echinoids, resulting, after several years' work, in a monographic study of the whole group as represented on this coast. Another group to which small additions have very recently been made is that including the corals, which have been worked through by J. O. Nomland.

History of Vertebrate Palaeontology

With the exception of a number of scattered notes on the occurrence of vertebrate remains in various parts of the Pacific Coast region, the earliest publication on this phase of palaeontological work is that of Louis Agassiz, describing a fossil fish fauna obtained by the Pacific Railroad Survey in Tertiary beds of the Kern region in the southeastern part of the Great Valley of California. This paper, containing the description of eleven species of the shark-skate group, was published in 1856 and remained the largest contribution to our knowledge of the fishes of the region west of the Wasatch until the appearance of David Starr Jordan's discussion of the fossil fishes of California, in 1907, over half a century later.

Excepting the fishes described by Agassiz, very few vertebrate remains were discovered outside the region of eastern Oregon during the period of pioneer work under the government and state surveys. A few references were made to occurrence of fishes and cetaceans, and a small series of fragmentary specimens of land mammals collected by the Geological Survey of California from middle Tertiary to Pleistocene strata in the Sierra region of California was described by Joseph Leidy. Also a few fragmentary vertebrate remains were obtained near the region of Tulare Lake on the western border of the San Joaquin Valley, from beds near Livermore, and at other scattered localities. These collections included fragmentary material representing rhinoceros, two or more extinct horses, tapir, elothere, camel, bison, elephant, mastodon, great wolf, and lion. The most important of these descriptions of collections obtained in California is the assembling of data from all sources by Leidy in J. D. Whitney's great work on the gold-bearing gravels of the Sierra Nevada, published in 1879.

In 1868, Leidy published the first description of a West Coast or Great Basin Mesozoic reptile. His material consisted of several very fragmentary specimens from the middle Triassic of Nevada. No other paper in the field of reptilian palaeontology of the region appeared until 1895.

By far the most important contributions to our knowledge of the history of vertebrates in this West Coast region in the pioneer period are those originating in 1861 with the studies of Thomas Condon on the mammal faunas of the John Day region of Oregon. A small collection of the fossil specimens collected by Condon was obtained by Leidy and described in 1870. Following a period of ten years of exploration by Condon, Professor O. C. Marsh of Yale visited the John Day region in 1871, and began a series of explorations, resulting in the publication, between 1873 and 1894, of a series of seven or eight papers relating to the remarkable Tertiary faunas discovered.

In 1878, E. D. Cope began systematic collecting in the John Day region, with parties under the direction of J. L. Wortman and C. H. Sternberg. In over thirty publications issued between 1878 and 1889, Cope presented results of his important studies covering nearly the whole range of the Oligocene, Miocene, and Pliocene faunas of eastern Oregon and marking an important epoch in the development of American palaeontology.

It was toward the end of the pioneer period of palaeontological investigation that Major Hancock of Los Angeles called to the attention of William Denton of Boston the vertebrate remains in asphalt beds on the Hancock Ranch, now known as the place of occurrence of the Rancho La Brea Pleistocene fauna. Denton gave a good description of the locality, but his reference to the fauna in the Proceedings of the Boston Society of Natural History of 1875 seems to have escaped notice of all investigators until after the independent discovery of the significance of these deposits in 1905.

In the literature of California, Nevada, western Oregon, and Washington, there are sporadic references to occurrence of fossil vertebrates discovered in this field between the first and second periods: such are the mention of a very few mammal remains in the Great Basin Province discussed in King's Report of the Fortieth Parallel Survey in 1878, and the reference to occurrence of cetacean and sirenian remains in the marine deposits of California by Leidy, Cope, and Marsh.

Following the beginning of palaeontological work at the two universities of California, a study of the marine Triassic reptiles was begun by J. C. Merriam in 1895, culminating in the publication of a monograph on the new order Thalattosauria in 1905 and one on the Triassic Ichthyosauria in 1908, the latter setting forth such evidence on the evolution of the ichthyosaurs as was then available. Work on the John Day faunas by parties from the University of California in 1899 and 1900 led to a series of papers including studies of the faunal sequence, discussion of the principal groups, and a summary of the fauna by J. C. Merriam and W. J. Sinclair between 1902 and 1907.

Mammalian faunas of three important Pleistocene caverns of California, represented in Potter Creek, Samwel, and Hawver caves, were secured and described by Sinclair, E. L. Furlong, and Merriam between 1902 and 1909. These studies gave for the first time a knowledge of the Pleistocene mammals in the higher, partly forested areas of the California region, and opened one of the most fascinating phases of study in the field of mammalian history.

In 1901 an expedition from the University of California visited the Fossil Lake Pleistocene of eastern Oregon and secured a valuable collection, of which the bird remains have been described by L. H. Miller.

Previously unknown Tertiary deposits representing the middle Miocene and the Pliocene in northwestern Nevada were explored by parties from the University of California in 1906 and 1909. The faunas of these deposits were described by J. W. Gidley, E. L. Furlong, Miss Louise Kellogg, and J. C. Merriam, between 1907 and 1910. The most significant contributions in this work were the additions made to our knowledge of the earlier Pliocene, heretofore unknown in the western area with the exception of a meager fauna from the Rattlesnake beds of the John Day region. Indication was also given of the broader relations of this fauna to those of the Great Plains region of America and of Old World areas such as China, India, Persia, Greece, and France.

Between 1911 and 1915, University of California parties worked over previously unexplored mammal-bearing formations of the Mohave Desert area and brought to light faunas representing at least four stages of the Cenozoic sequence. Of these the Phillip's Ranch middle or lower Miocene, the Barstow upper Miocene, and the Ricardo lower Pliocene were represented by mammal assemblages previously unknown in the region west of the Wasatch. The Manix fauna of the Mohave area is the best known group of Pleistocene forms obtained from any one locality in the Great Basin region. The Manix Pleistocene and the Phillip's Ranch Miocene have been described by J. P. Buwalda, the discoverer of these two very interesting faunas.

An important mammal fauna of the Great Basin Miocene was obtained near Cedar Mountain in 1912 by C. L. Baker and J. P. Buwalda.

In 1905 a small amount of material secured by W. W. Orcutt of Los Angeles furnished the motive for beginning extensive work on The Rancho La Brea Pleistocene fauna, and for the initiation of a series of publications continuing through numerous issues of bulletins in the University of California Publications up to the present time.

The great quantity of bird remains secured at Rancho La Brea was made the basis of L. H. Miller's first study of the fossil birds of the Pacific Coast region, this work being later extended to include all avian remains from the West Coast. Many papers have been contributed by Dr. Miller and the results of his studies in this field constitute one of the unique and important contributions to American palaeontology.

Preliminary papers on the carnivores and ungulates of Rancho La Brea have been published by J. C. Merriam. Studies on the Pleistocene rodents have been contributed by Miss Louise Kellogg and Lee R. Dice. An exhaustive study of the edentates of Rancho La Brea now in progress by Chester Stock has been extended to include the whole problem of edentates on the West Coast. Other contributions to the study of the ungulates from the asphalt beds have been made by W. P. Taylor and A. C. Chandler, while the batrachians have been reported upon by C. L. Camp.

Not the least significant of the studies in vertebrate palaeontology on the West Coast are those concerning the faunas of mammal-bearing deposits having a well understood stratigraphic relation to the marine Tertiary series west of the Sierra Range. Especially important are the collections obtained by parties working in the Coalinga region under the leadership of Bruce L. Clark in 1913. Mammal material secured at that time represents at least three important horizons of the Miocene and Pliocene. These collections may with some degree of satisfaction be compared with the Tertiary mammal series of the Great Basin region, and furnish the most valuable evidence bearing on correlation between the Great Basin and Pacific Coast formations thus far obtained.

Growing out of the work in vertebrate palaeontology west of the Wasatch, has come an effort to construct a correlation scheme of the mammal-bearing Tertiary formations of the Great Basin Province for use in fuller understanding of the palaeontological sequence. The correlation plan includes consideration of evidence of any and every kind that may be used to furnish us with information concerning the time relations of formations and their contained faunas. This work, under way for many years, can obviously never be completed. It is being presented for publication in the form in which it stands in 1917. As an outcome of the correlation it has become clear that further progress in our mammal history can be advanced most quickly by careful mapping and detailed study of the faunal zones in an area containing a considerable portion of the Cenozoic section. Such an area is found in the John Day region of Oregon. Through coöperation with the United States Geological

Survey and the University of Oregon work on a detailed monographic study of this region was begun in 1916. Intensive study of a small portion of the most imperfectly understood part of the section, represented by the Rattlesnake Pliocene and Mascall Miocene, has given unexpectedly large returns. Continuation of this work promises the beginning of a new epoch in interpretation of West American vertebrate faunas, and will greatly increase the scope of our studies so far as we have relation to world problems of evolution and distribution.

The most recent and one of the most interesting contributions to Pacific Coast palaeontology is that of Childs Frick, who, with unexcelled patience and persistence, has secured from the apparently barren hills of San Timoteo near San Bernardino, California, a series of Pliocene to Pleistocene mammal assemblages. These faunas include, with Asiatic types like the great bear, *Hyaenarctos*, one of the most interesting series of specimens suggesting the origin of the modern horse, *Equus*, that has yet appeared in America.

Studies of the fossil marine mammals known in West Coast deposits were planned beginning in 1895, but have only recently been realized in part through a review of all known pinniped remains from these deposits by Remington Kellogg.

Other studies of vertebrate faunas now under way, and to which reference might be made, include the discussion of a considerable number of special groups as the antelope-like ungulates, and the cats. Among the marine forms the cetaceans are being investigated. As yet comparatively little is known of this last group although excellent collections are already assembled for study.

Vertebrate palaeontology in the West Coast region has not yet reached the stage of development of invertebrate palaeontology in completeness of material available. In other particulars, as in the study of biological groups and evolutionary series, it is in many respects in advance of invertebrate study, excepting that aspect of it so remarkably exhibited in James Perrin Smith's work on the Cephalopoda.

History of Palaeobotanical Investigations

Our knowledge of the history of plants in the Pacific Coast region is much more imperfect than that of invertebrates or of vertebrates.

During the pioneer period, the attention given to plants was not comparable to that bestowed upon either group of animals. During the second period the absence of local palaeobotanists has greatly retarded progress in this particular field. Up to the present time, a large part of the work done on the Pacific Coast has been carried on with the assistance or through the coöperation of the United States Geological Survey.

The earliest publication on palaeobotany of the West Coast known to the writer is one published by Leo Lesquereux in 1859 in the American Journal of Science and covering descriptions of "Some Fossil Plants of Recent Formations," including species from Vancouver Island and Bellingham Bay, Washington. In 1883, J. S. Newberry of Columbia University published descriptions of sixteen new species of plants from the flora of the John Day region, this material having been obtained by Thomas Condon. In 1878, Lesquereux published a monograph of the Auriferous gravel flora in connection with J. D. Whitney's great report on the gravels. In 1883, Lesquereux in his monograph on Cretaceous and Tertiary floras described large collections from the Eocene and Miocene of the John Day region obtained by C. D. Voy, a professional collector from California. In 1889, Lesquereux published again a large series of species from the same horizon in the Proceedings of the United States National Museum.

One of the most important contributions concerning the Mesozoic flora of the Pacific Coast is a paper by William Fontaine on the Jurassic flora of Douglas County, Oregon, published in 1905 in a monograph on the Mesozoic flora of the United States by Lester F. Ward, Fontaine and others. In the same work is an important article by Fontaine on the flora of the Shasta group of California.

Significant work on the fossil plants of the Pacific Coast region is that carried on by F. H. Knowlton of the United States Geological Survey within the second period of palaeontological study on the West Coast. The work of Knowlton includes an intensive study of large collections representing the Puget flora from the Eocene of Washington, as yet unpublished; a complete revision of the Tertiary flora of the John Day region in eastern Oregon published in a bulletin of the Geological Survey in 1902; and a revision of the flora of the auriferous gravels of California and allied floras appearing in Lindgren's paper on the Tertiary gravels of the Sierra Nevada of California published as a Professional Paper of the United States Geological Survey.

Dr. Knowlton's studies of the fossil plants of eastern Oregon have shown clearly the presence of at least flour floras: two in the Clarno Eocene, one in the John Day Oligocene, and one in the Mascall Miocene.

Dr. Knowlton has also discussed in detail the problem of the Jurassic age of the supposed Jurassic flora of Thompson Creek, Oregon, and in numerous other short articles, either independent or accompanying reports of the Geological Survey, he has added much to our knowledge of the Tertiary floras of the whole western region.

In spite of the good work of Dr. Knowlton and others, the problems of West Coast palaeobotany are at the present day in a stage much further from final clarity than those in other phases of palaeontological investigation. A nearly continuous procession of expeditions from universities and from various government organizations has spent years of work in collecting vertebrates and invertebrates for the purpose of increasing our series to such a point that we may better understand the biological and time classification of the groups concerned, but our study of the history of plants has been based almost entirely upon more or less incidental collecting in field operations carried on for purposes other than palaeobotanical research, and covers an exceedingly short period compared with that given to study of other groups.

Conclusions

The relative isolation of the field for palaeontological study on the western side of the continent has tended to distinguish to some extent the problems of this area from those of the lands to the east. Separated as the Pacific Coast is from other regions by high mountains and wide oceans, it is natural that its isolated investigators should tend to separate their special researches rather widely from those of other workers. It is also clear that in past periods the life of this province has in its evolution tended to take on provincial characters differentiating it to some extent from that of other parts of the world. It is, however, true that the study of every group leads finally to a point at which we find ourselves forced to relate our local problems to the great world questions of life history.

In certain aspects the history of life on the Pacific Coast is imperfectly recorded. In other phases the information is available, but is as yet only partially examined. For a considerable portion of the earlier story of life we have only a meager record compared with that of the Atlantic Coast. Our history of plants is largely that of the later periods. Of the age of amphibians we have no amphibian record. Of the wonderful world history of the great reptile group, we know but a limited portion of the story of two divisions. In the history of mammals we lack entirely the long record of Eocene time. After subtraction of the factors which are poorly represented there is, however, enough remaining to give us a most extraordinary history compared with that of most portions of the earth's crust. Progress in our difficult work of interpreting this record has already been made, but the labor required to obtain adequate understanding of the history of this region must stretch far into the coming centuries before the end will be in sight.

The next four or five decades will see great advances in interpretation of detail in sequences of local faunas. We shall finally build up a system in which our West Coast correlations will become consistent with themselves. At the same time there will be a reaching out to obtain an interpretation of local evolution through knowledge of the great waves of world migration of organisms, and through better understanding of the complicated physical history of this planet. In time our story will be fitted into that of America in the large and ultimately it will become an interpretable part of the complicated record of life progress for the earth as a whole. Only the beginnings have been made—the real problems are yet to be solved—the broader contacts are still to be made.

As I conclude the thought uppermost in my mind concerns especially the part which our western work should have ultimately in assisting to interpret the world scheme of evolution, but in framing a vision of the larger use of the materials in process of accumulation we must remember that this object is to be attained only through coöperation and assistance of our colleagues across the continent to the east and over the ocean to the west.

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The following titles are not intended to furnish a complete list of contributions to the palaeontological literature of the Pacific Coast and Great Basin provinces. The list is divided into three sections, namely, (1) Invertebrate Palaeontology, (2) Vertebrate Palaeontology, and (3) Palaeobotany.

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SYNOPSIS OF LECTURES IN PALAEONTOLOGY [1]

PRINCIPLES INVOLVED IN A DISCUSSION OF THE HISTORY OF LIFE

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Definition and Scope

Palaeontology is a study of the *history of life*. It includes all information concerning the structure, mode of life, distribution, and evolution of the living world of past ages. It comprises a study of the modes of preservation of the remains of animals

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and plants from which our information is obtained, and of their occurrence in the succession of rock strata.

Palaeontology is intimately related on the one hand to biology, through which we obtain our basis for interpretation of the structure of living forms of past time; on the other hand, it is closely related to geology, through which we determine the order of succession of types of life in the time periods which the strata represent.

Palaeontology is essentially a historical science, and its most significant results are those which present the evidence of growth or evolution of existing life from the simpler or less advanced life of early periods.

Though it is based on fragmentary remains representing the living forms of past ages, palaeontology is a *study of life* and *not merely of fossil remains*.

AN ACCOUNT OF THE DEVELOPMENT OF PALAEONTOLOGY

Palaeontology is necessarily a world science and was therefore late in developing. A record of the life of past ages cannot be obtained at any one locality. Investigation of a large part of the earth's surface was necessary before a satisfactory interpretation of life-history became possible. In early days scientific men were few in number, and had access to only a small portion of the earth's surface. Increase of wealth of the world, exploration, rapid transportation, and inexpensive printing have made recent advances possible.

Belief in spontaneous generation made a theory of evolution unnecessary until recently, and an evolutionary science such as palaeontology could not easily develop.

Deluge and Creation Myths.—Hindoo, Chaldean, Egyptian. Priest class intelligent, unbiased. Myths stated that the world was destroyed by *deluge*. Possible explanation: (1) Inspired writers reported events, of which they had no personal knowledge. (2) Finding of remains of marine animals on high land far from sea suggested a rushing of the restless sea over the unmoving land, destroying land animals and washing seashells upon the land, burying all in mud and sand. *Creation myths* with recurrent periods of creation and destruction may have been suggested by seeing in the same rock series several strata with different kinds of shells or bones. (3) Deluge myths may have originated in accounts of destructive floods visiting small communities. Later, wide distribution of remaining people caused expansion of the legend to cover more territory and include more people.

Greeks.—In main unprejudiced, clear thinkers in science as in philosophy. Pythagoras, 6th Century B.C. World in constant state of change. Sea might become land, or land sea. Found seashells and an anchor on eminence far from sea. Aristotle mentioned fossil fish and understood them to represent creatures that once lived in the sea.

Romans.—Advanced science but little. Strabo, the geographer, ascribed geologic changes to natural forces similar to those now in action. Emperor Augustus had a villa ornamented with bones of large extinct mammals.

Priests and Teachers of Middle Ages.—Conserved knowledge, but did not advance it largely. Introduction of Bible as new factor controlling interpretation of available knowledge. Fossil remains considered as: (1) Sports or accidents of nature. (2) Due to influence of stars. (3) Due to peculiar plastic force in nature. (4) The remains of creatures destroyed by the Mosaic deluge. The last view recognized the organic nature of fossils, but ascribed remains from all past periods to burials by water in a few days. Did not take into account the fact that different strata contain different kinds of fossils.

Leonardo da Vinci, 1452–1519, Italy. Great artist, musician, engineer. Claimed that fossil shells found in an excavation were remains of animals that once lived in the sea. Had been covered with mud and left by receding water. Was the first of the unbroken chain of palaeontologists extending back from the present period.

John Woodward, 1695, England. "Essay towards the natural historia of the earth." Recognized organic nature of fossils, as debris of animals destroyed by deluge.

J. J. Scheuchzer, 1708, Switzerland. "Complaint and Vindication of Fishes." Fishes complained that being destroyed by the flood, brought on by man's iniquity, men now refuse to recognize the organic nature of fossil fishes. Recognized organic nature of fossils of many kinds and ascribed them to action of deluge.

Amateur Collecting of 17th and 18th Centuries. German professor who collected fossils of all kinds, including inscriptions, and finally found his own name fossil in the rocks. Much valuable material was obtained during this period.

Hook and Lister, 1705, England. Recognized that *different strata contained different fossils*. Hook recognized organic nature of fossils, Lister did not.

G. Cuvier. Worked back known Recent fauna to older and slightly different ones—from known to unknown. Used *law of correlation of parts*. All parts of an animal related in function; from any part we learn general plan of animal; very useful in study of fossils, where commonly only parts of skeletons are present. He considered faunas of different geological horizons as totally different; may have believed in periods of complete destruction followed by periods of creation.

H. G. Bronn, Germany. *Species may run from one formation to another*. No complete destruction.

Sir Charles Lyell. Great *physical catastrophes* shown to be *unnecessary*. Geological events due to action of forces similar to those now in operation.

Charles Darwin. *Biological discontinuity unnecessary*, as one species may be derived from another. Life of present period derived from life of earlier periods. Palaeontology becomes a history of the descent of organisms which are connected by blood relationship.

Recent Contributions. Rapidly closing up the gaps in the evolutionary history: show man to be descended from mammals of earlier periods. Existing life to be interpreted largely in terms of antecedent life from which it is an outgrowth.

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Cuvier, G., Revolutions of Earth's Surface.

Nature of Fossils as Now Interpreted

Fossils are any traces of organisms preserved in deposits formed in past geological periods. (Traces—impression—to complete animal: organism—living thing, plant or animal.)

Not all fossils petrified—petrifactions are not necessarily fossils.

Not all fossils extinct—extinct forms not necessarily fossil, e.g., dodo, Steller's sea-cow.

Present period extends back to last great physical event in this region, or to last great changes in life. Changes in fauna and flora generally occur some time with physical changes and are conditioned by them. Physical events generally expressed in terms of crustal movements, which make strata of a later period occur in a new basin, or tilt the older strata so that the later ones are not parallel with them—e.g., Pleistocene beds at Pinole are elevated above sea-level. They contain remains of sea-shells now living, as oyster, mussel, razor clam; but the razor clam is no longer living north of southern California. They contain also remains of mammal species, as horses, bison, camel, ground-sloth, mammoth, which are all extinct.

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Modes of Preservation of Animal and Plant Remains

Original material. Complete mammoth in Pleistocene ice; with bones, hair, skin, flesh, nerves, veins, contents of stomach preserved intact. Shells from Eocene period show color bands and spots. Wood from Miocene period unchanged. Bark from trees of Carboniferous period very slightly changed. Insects, etc., in amber. Teeth with worn surfaces which were rubbed down in biting.

Carbonization. Reaction of the components of a body on each other leaving a residue representing original form and internal structure. Occurs where there is a relatively large carbon content. Coal is carbonized plant remains.

Incrustation. Covered with a layer of deposited material. Original body encrusted may disappear in time. Formed commonly in strongly calcareous springs—leaves, sticks, moss.

Impression. Of a shell, bone, wing, foot, feather, raindrop—moulds, casts.

Petrifaction. A replacement in which the original material is removed in fine particles and replaced, usually by silica—the original microscopic structure being retained. Petrified wood.

Where Fossils are Found

Igneous rocks. Rocks which have been in a molten state, lavas, etc. Fossils rare here.

Sedimentary rocks. Deposition of fragments of other rocks or accumulation of skeletons of animals or plants, or rarely a chemical precipitate. Fossils most common here. The quantity of specimens found is often very large.

Metamorphic rocks. Altered igneous or sedimentary rocks. Fossils usually destroyed in process of alteration.

Fossils are buried in most natural ways. Buried in sand or mud on floor of sea. Washed by streams into lakes. Covered by a dust or soil on the land. They are preserved where the accumulation is thick enough to keep them protected.

Many organisms, particularly those with calcareous or silicious skeletal remains, accumulate in sufficient quantities to form rock masses.

Examples. Forms with calcareous skeletons, foraminifera (chalk, limestone, nummulitic limestone), corals, crinoids, brachiopods, molluscs (limestones). Forms with silicious skeletons, radiolario (radiolarian chert), diatoms (diatomaceous earth or shale).

The Geological Scale in Relation to Succession of Life Forms

Geological Scale

Eras	*Periods*
Psychozoic	Recent
Cenozoic	Pleistocene
	Pliocene
	Miocene
	Oligocene
	Eocene
Mesozoic	Cretaceous
	Jurassic
	Triassic
Palaeozoic	Carboniferous
	Devonian
	Silurian
	Ordovician
	Cambrian
Proterozoic	Keeweenawan
	Animikean
	Huronian
Archeozoic	Schist Series—Granitoid Series

Nature and Mode of Construction

A double scale. In the physical scale *systems* represent sequence of rock strata. In the time or life scale *periods* represent succession of time and of life forms.

Rock Systems generally accumulate in nearly horizontal layers. Sedimentary rocks are formed of layers of fragments deposited. Igneous rocks may be poured out on surface and form layers. The first solid outer layer was presumably igneous material.

Sediments accumulate in basins and cannot form to great thickness unless the basin is very deep, or unless its floor sinks. Basins of deposition are usually under water, and material is brought in by streams. When the accumulation reaches the surface of the water it usually ceases. Some basins of accumulation on land receive mainly dust and volcanic ashes. After accumulation of deposits, uplifts may fold the strata, and erosion effected through the agency of wind and water may carry a large part of the deposit into a newly formed basin. No complete record in any one locality. Overlapping sets of strata give us a nearly continuous history of sedimentation. The total thickness of stratified rocks known aggregates from 100,000 to 250,000 feet.

The strata representing continuous sedimentation in any region are called a *stratigraphic unit* or *system.* Systems are generally separated by unconformities. *Unconformities* are breaks in the stratification due to *interruption of sedimentation*, the lower strata usually having a position somewhat different from that of the upper ones owing to movements of the earth's crust intervening between the periods of deposition.

The *units* of the *time* and *life scale* are based largely on the periods of dominance of the important types of life, e.g., periods of dominance of fishes, amphibians, reptiles, man.

Fortunately the changes in physical conditions causing readjustment in deposition of systems have also influenced life, so that the times of deposition of systems have generally coincided with periods of dominance of organic types, and the lines in the two scales fall together.

Names in geological scale vary in significance. Local (Cambrian = Cambria, Devonian = Devonshire). Mineralogical (Carboniferous = Carbon-bearing, Cretaceous = chalky). Tertiary = third division of the old scale.

In constructing the geological scale it has been necessary to fit together many scattered parts of the record. This involves comparing fragments of records to see what their time relations are to each other, whether one is older, younger or of the same age as another. This is geological correlation.

Geological correlation is a comparison of formations, assemblages of life forms (faunas or floras) and of geological events, with a view to determining their time relations.

The criteria or standards of correlation may be classified as follows:

Inorganic	Biologic
Stratigraphic	Identity of species
Lithologic	Percentage method
Crustal movements	Stage of evolution

The inorganic criteria are based on a study of the relations of strata to each other.

The *stratigraphic* method consists in determining whether a stratum of unknown age rests above or below a bed of known age or is perhaps continuous with it. Continuous beds are generally of the same age throughout, beds above are younger, beds below are older. This method is generally not applicable when strata compared are widely separated geographically.

The *lithologic* method is a comparison of kinds of rock, as limestone, sandstone, shale. Beds of a similar nature in the same region are frequently, but by no means always, of the same age. A layer of volcanic ash over a wide area may correlate deposits formed at the same time on land and in the sea—this is otherwise difficult.

A comparison of the history of *crustal movements* may show that different beds in separated regions all have the same relation to a widespread unconformity and thus approximate the relative ages of the strata in question.

The biologic criteria are based on three important principles distinctly shown in the history of life: (1) Biologic species, or kinds of animals and plants, live but a short time judged in terms of the known geologic history. (2) A given species appears but once in the history of the world. (3) The life of the earth shows a continuous tendency to specialization, or to advance to higher and higher levels.

Strata having *identical* species are of the same age. Species of organisms have a comparatively short geologic range, and appear but once in the earth's history. The same species occurring in separated deposits indicates that the beds are of approximately the same age.

As species have fairly definite life periods, we may calculate the relative ages of beds not widely separated in time by determining the *percentage of species* common to the beds compared. Using mollusca, the percentages which have been in general use are approximately as follows:

All the species the same = same age.
90% same = one period removed, may be earlier or later.
25% same = more than one period removed.
No species common, sharply separated in time.
Recent 100% living species.
Pleistocene 90% same as Recent.
Pliocene 60% same as Recent.
Miocene 25% same as Recent, and 60%–90% same as Pliocene.
Eocene no species same as Recent.

This method is particularly valuable in comparing beds having no species identical but having enough Recent species present to make possible determination of their approximate stage of removal from the present period.

Use of the criterion of *stage of evolution* depends on fact that from period to period there has been a gradual progression of the highest types toward a more efficient form of organism. Ordovician—highest type crustacea and mollusca; Devonian—fish or possibly amphibia; Carboniferous—amphibia and Reptilia; Triassic—mammalia; Recent—man.

There has always been a tendency to specialize, even in groups which have not actually progressed. In the Devonian no clam had a siphon or neck; in the Cretaceous many had siphons.

Correlation by stage of evolution requires a good representation of the life of a given period. Working between widely separated regions it is very useful.

It is very important to determine the time relations of all strata to all other strata. Palaeontological history is a world science and we must bring the succession of events in all parts of the world into comparison, in order to determine some of the most important facts in the history of migration of organisms.

Huxley proposed term *homotaxis* for similarity of arrangement of beds when exact correlation is impossible.

Synchrony is identity in time. This is the goal of geological correlation.

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Schuchert, C., Historical Geology, pp. 440–455.
Williams, H. S., Geological Biology, pp. 40–77.

Amount of Time Represented by Geological Record

Lyell's theory regarding physical events and Darwin's theory of evolution require much time during past geological periods.

Time determined by physicists in many ways. Examples as follows:

Retardation by tides. Present form of the earth would not be given by present rotation. Tides retard rotation. Calculate amount of retardation and how long it has taken to slow the earth down to present speed from speed at which present form was produced.

Radiation. Calculate how much heat is given off by earth and how long with given rate of radiation since earth was first habitable.

Radioactivity. Calculations of rate of radiation of minerals having a definite age-relation to rocks having a clearly determined position in the geological column.

Determined by geologists by *determining* the *thickness* of *stratified rocks*, 100,000 to 250,000 feet and calculating the *rate of deposition per foot* (1 foot requires 700–6000 years).

Computations average remarkably near together and indicate an age of more than 10,000,000 years. Probably between 25,000,000 and 100,000,000 is a fair estimate of time available for the rocks containing the palaeontological record. This is sufficient to satisfy inorganic geologists and biological evolutionists.

Reference:

Holmes, A., The Age of the Earth.

Relation of Palaeontology to Classification of Organisms

A vast number of kinds of organisms known. Each kind must have a distinct name. Kinds grouped first for convenience. Are generally grouped as follows, using a museum specimen of *Pecten caurinus* as an example:

Individual	No. 11364, Univ. Calif. Collections
Species	caurinus
Genus	Pecten
Family	Pectinidae
Order	Asiphonida
Class	Pelecypoda
Subkingdom	Mollusca
Kingdom	Animal

In the grouping of individuals the *species is the unit group of classification.* A species has been defined in most general terms as "a group of individuals which in the sum of their characters resemble each other more than they resemble other individuals, and differ from each other less than they differ from other individuals." Species is hard to define and hard to delimit. In most cases distinct species do not cross-breed and produce fertile offspring. The test is generally found in the presence of constant characters.

Origin of species. (1) Created as they now exist, in genera, families, etc. (2) Created from time to time, but without any relationship of successive series of species. (3) All life descended from previously existing life; new species appearing on the earth in successive periods and derived by modification from preceding species. Evolution.

Views as to mode of evolution. Lamarckian—Use and *disuse* and inheritance of acquired characters. New characters produced through variation in a degree of use or disuse of structures. The giraffe's neck grew long because he stretched it continually. Loss of side toes on foot of horses through disuse in standing high up on longest or middle toe. *Darwinian—Natural selection.* Survival of the most fit and elimination of the least fit. Dependent on the fact that no two individuals are originally alike. In any set of conditions some forms are better fitted to environment than others. *De Vries—Mutation hypothesis.* Species change suddenly to another form. Based on actual observations in a few cases. A statement of occurrence and not an explanation. May be due to purely chemical basis of characters of species. Chemical changes sudden and not transitional. *Mendelian*—Results of mixtures of stocks. *Isolation*—Results of geographic and other modes of separation of stocks. *Orthogenesis*—A tendency of many forms originally from the same stock to vary in the same direction, although under somewhat different surroundings, suggesting an original innate tendency to variation in a definite direction. Seen best in palaeontological succession of tooth series of mammalia.

Death of species. Bears on nature of the thing called a species. Species seem to have a definite life period. Species of most highly organized forms geologically shortest lived. Mammalian species usually live about one epoch; Protozoan species may live several geological periods.

A species composed of many individuals is sometimes compared to an individual composed of many cells. The death of species has been attributed to the following causes: (1) Old age—(Trilobites) a running out of the type due to unknown causes. Perhaps similar to old age in individuals. (2) Changes due to general evolution, one form changing into another (Horses). (3) Overbalanced specialization (Sabre-tooth). (4) Accidents (Mosasaurs).

What Biological Classification represents. The basis of biological classification is *blood relationship or descent.* At the present time many groups include forms which are superficially similar but are not derived from the same immediate ancestors. These are called groups of polyphyletic origin. Natural classification is best represented by the arrangements of groups as the stems or branches of a tree; the base of the trunk rising upward from the earlier geological periods, the tips of the topmost branches reaching up to the present period. Many branches died out in early geological time.

The time relations of the groups may be represented by the following example, *Pecten caurinus:*

Species	caurinus	Miocene—Recent
Genus	Pecten	Carboniferous-Recent
Family	Pectinidae	Silurian-Recent
Order	Asiphonida	Cambrian-Recent
Class	Pelecypoda	Cambrian-Recent
Subkingdom	Mollusca	Cambrian-Recent

HISTORY OF GEOGRAPHICAL DISTRIBUTION IN RELATION TO EVOLUTION OF FAUNAS

According to the distribution of organisms, the earth's surface may be divided into numerous provinces. Each province has its peculiar flora or fauna. These provinces are conditioned or limited by the distribution of land and water, food supply, climate and the presence of enemies. In the water, the kind of water, whether salt or fresh, depth, the amount of light, motion, etc., have important influence.

Several explanations of the present distribution of organisms have been put forward. (1) That all groups of organisms were created where they are now found. (2) That there have been centers of creation in which there have been special manifestations of creative energy, large regions being populated from these centers. (3) present distribution has been ascribed to present climatic and general environmental conditions, each form being supposed to exist in the region to which it is best suited. No one of the above suggestions fully explains the present distribution of organisms.

From the standpoint of the evolutionist, the study of geographical distribution is of great importance. If similar groups of organisms are presumed to be derived from the same ancestors it will be necessary to account for the present situation of similar forms on widely separated parts of the earth's surface between which communication is now impossible. The only satisfactory way in which this phase of the subject may be approached is through a comparative study to the palaeontologic succession of faunas in all the regions of the earth's surface at all periods. The group of organisms which seem to furnish the most satisfactory record of this nature is the Mammalia. This group is at the present time distributed over the whole surface of the earth. It includes a great variety of forms and, although the life of the species is comparatively short, many stages of evolution have been passed through by the group. Some large groups of organisms have been on the earth for such a long period that they have migrated back and forth many times over the same region, and the record of their distribution has become very complex. In the case of the mammalia the life of the group is so short that the record of migration is still comparatively simple.

According to the distribution of the mammalia in the present geological period, the earth's surface is divided into three realms—the *Notogaeic Realm*, including Australia and a number of the islands of the Pacific region; the *Neogaeic Realm*, including South America and adjacent islands; and the *Arctogaeic Realm*, including North America, Europe, Asia, and Africa.

References:

Lydekker, R., Geographical History of Mammals, General statement, pp. 1–27; Notogaeic, pp. 50–63; Neogaeic, pp. 117–123; Malagasy, pp. 222–226.

Wallace, A. R., Geographical Distribution. Island Life.
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Scharff, R. F., Distribution and Origin of Life in America.

Notogaeic Realm

As regards its fauna and flora, Australia is probably the most unique region of the Recent geological period. The flora contains hosts of peculiar plants, of which the *Eucalyptus* and many other types commonly planted in California are examples. Many of the invertebrates, even those inhabiting the seas, are also peculiar.

In the mammalian fauna (excepting bats, rats, a dog and a pig) all the forms of Australia are pouch-bearers belonging to the two lowest mammalian subclasses, Prototheria and Metatheria.

Mammalian fauna of Notogaeic Realm includes representatives of all three of mammalian subclasses.

- Class Mammalia
  - Subclass Prototheria (Reptilian Mammals)
    - Duckbill, Echidna
  - Subclass Metatheria (Marsupials)
    - Diprotodontia $I\frac{3-1}{1}$ Canines small or wanting
      - Kangaroo family
      - Phalangers
      - Diprotodon
      - Wombats $I\frac{1}{1}$, $C\frac{0}{0}$
    - Polyprotodontia $I\frac{5-4}{4-3}$
      - Opossum family absent
      - Dasyures $I\frac{4}{3}$
      - Notoryctes (Marsupial moles)
      - Bandicoots
  - Subclass Eutheria
    - Bats (all families but South American)
    - Rodents (Rat family only)
    - Carnivores (Dog only)
    - Ungulates (Pig only)

Fauna made up almost exclusively of metatherians. Prototherians and eutherians relatively rare.

No living prototherians known outside of the Australian region and no marsupials, excepting the opossum of North and South America and one diprotodont in South America. The marsupials of Australia seemed to have followed lines of adaptation somewhat similar to those followed by the orders of the eutherian mammals in the rest of the world, e.g.: (1) insectivores (marsupial moles); (2) carnivores (marsupial wolf); (3) rodents (wombats); (4) ungulates (herbivorous kangaroo and *Diprotodon*). Restricted environment and a somewhat lower stage to start with have kept the number of types down and made the rate of evolution less rapid. If we examine the mammalian fauna of Australia with relation to the rest of the world we find that in Mesozoic era forms like the prototheres and marsupials were in existence over a good portion of the earth, and were the highest types of animals in existence. Later, in the Eocene, we find the marsupials existing in Europe and America. They are now confined to Australia, excepting the opossums and one diprotodont on the American continent.

The fauna seems not to have been connected with that of South Asia since late Mesozoic or early Cenozoic time. If it had been connected, we should find in it numerous representatives of the eutherian fauna, which was developing rapidly in all parts of the world at the beginning of the Eocene. Since late Mesozoic time Australia seems to have been isolated from the rest of the world. The eutherian mammals which arose out of the lower forms on some other continent were never developed in Australia, and the highest stock, the marsupials, followed as far as possible the same lines of adaptation in Australia as were followed by the Eutheria in other parts of the world. About the same number and same types of orders of marsupials in Australia now as in the eutherian group of the whole world in Eocene time.

The adaptive radiation of the marsupials in Australia did not reach such extremes as were reached in the Eutheria of the rest of the world. (1) Because the type was somewhat less intelligent and less vigorous, so that in the same length of time they would live less and not go as far in evolution. This is in accordance with the well-supported law that the lower the organism the less rapidly it changes. Compare length of life of protozoan or molluscan species with higher mammals for strongest contrast. (2) Because the region in which the evolution of the marsupials occurred was much more narrowly limited geographically and had fewer kinds of environment or sets of conditions with which to control evolution or to preserve such forms as might arise. (Had Australia been one continuous barren plain or one great swamp the amount of variation would have been less than we now find there.)

The diprotodonts appear to have arisen in or near Australia after its separation from Asia, as none is known in Asia. A few, however, are known in what is now the region most widely separated from Australia of all land areas of the globe, viz., South America. This relation of the fauna is better understood when taken up with the study of the South American fauna.

Australia and Correlation by Stage of Evolution. Would the present Australian fauna be correlated with that of the Mesozoic of the rest of the world because entirely metatherian and prototherian? No, because the stage of differentiation would be higher than that of the Mesozoic faunas of other parts of the world and the area in which the differentiation occurred is relatively small, so that one would expect less differentiation than, for example, in Arctogaea.

Neogaeic Realm

Mammalian fauna

Recent	Miocene
Primates	Primates same as Recent fauna
Spider monkeys, $P\frac{3}{3}$, $M\frac{3}{3}$	
Marmosets, $P\frac{3}{3}$, $M\frac{2}{2}$	
Carnivora	No carnivora
Wolves	
Bears (spectacle bear)	
Raccoons	
Weasels	
Cats	
Bats	Bats unknown
Insectivora	Insectivora imperfectly known
Ungulata	Ungulata
Deer	None of recent orders; three orders present that are now extinct and are not known elsewhere, Recent or fossil
Pigs	
Camels (llama)	
Tapirs	

Rodentia	Rodentia present
Edentata	Edentata present, and with more groups; of the earlier groups the ground sloths and glyptodonts are now extinct
Sloths	
Armadillos	
Anteaters	
Metatheria	Metatheria present, as in Recent fauna, but more numerous
Polyprotodonts	
Opossums	
Diprotodonts	
(One small form)	

The recent South American fauna includes: (1) types which were developing in South America in middle Cenozoic time, as the primate and edentate groups; (2) types which had a world-wide distribution in early Cenozoic time, as the polyprotodont marsupials; (3) diprotodont marsupials, which are possibly derived from Australia; (4) carnivores and ungulates, which are immigrants from North America.

In Miocene time North America and South America contained almost no common elements in their faunas. In Pliocene time elements of each fauna suddenly appear in the other. This indicates geographic separation in the Miocene and union in the Pliocene. The stronger northern fauna replaced much of the original South American fauna. No South American forms obtained a foothold in the middle North America.

Some of the oldest and simplest types of mammals and reptiles in South America suggest a connection with Africa and with Australia in early Cenozoic time. The presence of similar plants and animals in South America, South Africa, and Australia in early Mesozoic rocks indicates the existence of a great southern land mass about the pole in Mesozoic time. These land connections may have persisted to some extent into Cenozoic time.

Arctogaeic Realm

Mammalian fauna of Madagascar or Malagasy Region

MADAGASCAR	AFRICA
Recent fauna, non-flying mammals	Recent fauna, non-flying mammals
Primates	Primates
	Apes (Simiidae)
	Monkeys (Cercopithecidae)
Lemurs (Lemuroidea), 38 sp.	Lemurs (Lemuroidea)

Insectivora	Insectivora
Tenrecs (Centetidae), 9 sp.	Five families
Musk shrews (Crocidiura)	
Carnivora	Carnivora
	Cats (Felidae)
Civets (Viverridae), 7 sp.	Civets (Viverridae)
	Dogs (Canidae)
	Hyaenas (Hyaenidae)
	Weasels (Mustelidae)
Rodentia	Rodentia
Rats (Muridae)	Rodents
Ungulata	Ungulata
Pigs (Suidae), bush pig	Pigs (Suidae)
Hippopotamus	Hippopotamus (Hippopotamidae)
	Giraffes (Giraffidae)
	Antelopes (Antilopidae)
	Cattle (Bovidae)
	Tragulines (Tragulidae)
	Rhinoceros (Rhinocerotidae)
	Horses (Equidae)
	Elephants (Proboscidea)
	Hyrax (Hyracoidea)
	Edentata (anteaters)

The mammalian fauna of Madagascar contains a considerable number of species in only a few primitive types. The neighboring continent of Africa contains but few of the primitive types and many advanced forms.

The reptilian fauna is more like that of Africa than is the mammalian fauna, and finds its nearest relations in Africa. The mammalian fauna shows more resemblance to that of Africa than to any other region. It is nevertheless distinct from that of Africa, as from all other parts of the world. Hippopotamus, pig and musk shrew common to Africa and Madagascar. The first two probably swam over, the third may have been introduced by man.

Madagascar could not have been connected with the mainland of Africa since early Miocene times, or it would have received many of the higher ungulate, carnivore and primate types which were there at or near that time. It was perhaps connected when the lemurs and primitive civets were common forms. Insectivores and rodents of the rat type were also very widely distributed at that time.

On the other hand, the presence in both Africa and Madagascar of such familiar forms as the true lemurs with a caniniform P_1, also the galagine lemurs with a peculiar elongation of the foot, shows that the connection was possibly not remote. Time must have been given for the development of these groups before the separation of Madagascar, and at the end of the Eocene these modern groups are not known to have existed.

Checking from both sides, as has been attempted here, seems to indicate that the separation probably occurred in Miocene time, and that since then the independent evolution of the isolated groups has gone on much as in the case of the marsupials of Australia.

The existing fauna shows evidence of separation at an early date, and the time for evolution of the group is not short. The failure to show a wider range of adaptive radiation is due largely to the limitations in environment, and to the fact that the types were already quite specialized before they were isolated—more specialized than the early Australian marsupials.

Some investigators hold that the Madagascar fauna has been introduced since isolation of this land mass.

Mammalian fauna of Sonoran region

Including approximately the region of the United States

N = Native. O = Old World origin

Recent Fauna	Miocene Fauna
Eutheria	
Carnivora	Carnivora
Wolves, N	Dogs, N
True cats, O	Sabre-tooth cats, N
Weasels, N	Weasels, N
Raccoons, N	Raccoons, N
Bears, O	
Ungulata	Ungulata
Deer, O in part	Deer-antelopes, N
Bison, O	Pigs, N
Pigs, N	Elotheres, N (now extinct)
Antelope, N	Horses, N
Sheep, goat, O	Rhinoceros, N
	Tapirs, N
	Camels, N
	Mastodon, O
	Oreodons, N (now extinct—most characteristic group)

Insectivora	Insectivora
Moles	Probably much as now, but not so specialized
Shrews	
Rodentia	Rodentia
Squirrels, N	Squirrels, N
Rats, N	Rats, N
Porcupines, N	Beavers, N
Rabbits, N	Rabbits, N
Bats	Bats not known because remains are so fragile and hard to preserve
Edentata	Edentata absent
Armadillo, rara (South America)	
Marsupalia	Marsupalia absent
Polyprotodontia (Opossum) (South America)	

A study of the existing mammalian fauna of North America shows it to be composed largely of forms which originated here; but with these is a considerable number of types that are immigrants from the Old World. A very few have come from South America.

The forms which composed the Miocene fauna of North America are largely still here. Some large groups have disappeared entirely (oreodons, elotheres). Other groups which were very important here, and were not present elsewhere, have now disappeared from North America, but are flourishing on other continents (camels now in Asia and South America; tapirs now in East Indies and South America).

The history of North American mammalian fauna illustrated very well the great changes in distribution of faunas, which are a common feature of past history.

General Conclusions Derived from Study of History of Distribution of Mammalia

A study of the geographical distribution of the mammalia furnishes evidence of special value on the following questions:

(1) The distribution of land and water in past periods.

(2) The centers of creation—adaptive radiation.

(3) The validity of evolution theory.

A study of the history of geological distribution of the mammalia shows that it is *unnecessary to suppose* that the numerous distinct faunas now in existence have had *entirely distinct origins*. It is proven in a great number of cases that some of them were originally closely related. In many cases they originally inhabited the regions now occupied by entirely different groups of mammals. There have been many centers from which adaptive distribution has taken place. These might be called *Centers of Creation*, understanding creation to mean making of something entirely new out of something that already existed.

The present distribution of mammals does not show evolution to be impossible, but indicates that it is necessary to study the history of distribution in order to get any rational explanation of evolution. Just such a history of migration as we know was conducive to differentiation and consequently to some advance in the mammalian group. *Isolation* has protected some weak forms. It has allowed them to differentiate in adaptation to their surroundings when they would otherwise have been destroyed. Out of this radiation have emerged some groups which have later on been able to compete with many others. By *throwing together* of faunas there have come periods of acute competition, which resulted in the death of the weak races, and in the survival of the stronger.

Distribution of Aquatic Animals

Fresh-water animals. River systems and lakes have well-defined limits, and may be expected to have characteristic faunas. Recent studies of fish faunas have developed much of interest in this field of study. Sacramento, San Joaquin and Santa Clara rivers are connected and their fish faunas are the same.—Salinas, San Benito and Pajaro have different faunas.

The Columbia and Sacramento river systems are now separated but contain similar forms. There may have been some connection through lakes at an earlier period. The Klamath River contains a fish fauna different from both and must have been separated from both for a long period.

David S. Jordan has shown that the most nearly related species of fish are not in the same stream but in the nearest streams, showing that a slight separation is accompanied by a slight change in characters. This is taken to indicate that variation is in a large measure dependent on distribution.

Lakes sometimes originate from bodies of salt water connected with the sea. In the process of closing up the connection and freshening of the water, marine forms may be accommodated to fresh water, as in Lake Merced, San Francisco; or Lake Tanganyika in Africa.

Marine Animals. Fairly abundant down to a depth of 15,000 feet. Areal provinces exist in the sea, but are less sharply separated than on land, as the sea covers the greater part of the earth and is not readily cut up by the smaller land areas.

Classification of organisms according to locomotion or habitat. *Benthos*, bottom forms. *Nekton*, freely swimming active forms. *Plankton*, freely floating more or less passive life of open sea.

Zones of depth; organisms influenced by increased pressure, diminution of light, heat and motion.

Littoral (high-low tide).
Laminarian (low tide—90 feet).
Nullipore (90–250 feet).
Brachiopod (250–1500 feet).
Abyss (1500–).

The Deep-Sea Fauna consists in large part (*a*) of forms which are very vigorous and have a wide range, as some bivalve molluscs; (*b*) of forms which are limited principally by temperature; (*c*) of forms which are not vigorous enough to maintain themselves in the sharp competition of the shore fauna.

Many groups of animals which were once the most common forms in shallow water over the whole earth, and would have dropped out of sight except for their fossil remains, have been brought up by the dredge from the deep sea. Crinoids, deep-sea urchins with movable plates (known from Mesozoic). Brachiopods, glass sponges, etc. In dredging in the Caribbean Sea, sea urchins typical of the following ages were dredged, 5 Jurassic, 10 Cretaceous, 24 early Cenozoic, 4 late Cenozoic.

The deep sea differs in its isolation from such regions as Australia, as it will probably continue as a peculiar province to the end of time during which life exists on the earth. Like a great city of refuge. There not only do space limitations have less meaning as light is dim, but the Palaeozoic, the Mesozoic and the Cenozoic ages exist at the same time. Cannot be destroyed. Highlands may be worn down to sea-level and become plains, but the sea cannot be filled.

THE RELATION OF CRUSTAL MOVEMENTS TO THE EVOLUTION OF ANIMAL LIFE

The influence of crustal movements upon life has been considered an important factor in evolution, the movements furnishing the cause or perhaps the occasion of the advance.

Effect of Crustal Movements on Land Organisms.—The effect of crustal movements upon *land* organisms is much more easily shown than that upon marine forms, and is perhaps more marked. The total land area of the earth is at present only about one-third as large as that of the oceans, and we have no good reason to believe that it has ever been relatively much larger than it is today. The land is in more or less widely separated irregular masses of varying heights, and has an average height much less than the average depth of the ocean. A much smaller vertical movement of the crust will suffice to submerge a land area than is necessary for the emergence of a deep-sea bottom. The isolation of a land area or the throwing together of two adjoining ones is ordinarily much more easily accomplished than the isolation of any considerable portion of the main ocean.

Crustal movements may have an influence upon land forms.

1. By isolation of an area with its fauna, thus separating the fauna from competition with other groups.
2. By uniting land areas, and thus throwing groups together and into competition with each other.
3. By change of topography from flat to rugged or the reverse by vertical movement, and thus changing the environment.
4. By change of climate through elevation or depression, or by the introduction of a different system of air or water currents.

Under the first class, the movement which separated Madagascar from Africa and that which separated Australia from Asia seem to have checked progressive evolution to some extent in these regions through the limitation of competition. New groups, which might otherwise not have appeared, or would soon have been cut off, were, however, allowed to arise and develop.

In the second class, the effect of crustal movement in throwing two land areas together, allowing intermigration and causing heightened competition, is seen in the late Tertiary connection of North and South America (survival of fittest—which may have arisen in isolation). At this time North America was inhabited by a highly developed fauna of eutherian mammals comprising ungulate types represented by horses, rhinoceroses, cattle, tapirs, deer, camels, mastodons; and among carnivores, the cat, weasel, dog, and raccoon tribes; while in South America these forms were all absent and the mammalian fauna consisted of marsupials, ant-eaters, gigantic sloths and armadillos, long-tailed monkeys, certain peculiar ungulates known as the Toxodontia, etc. With the union of the two continents there came intermigration. The movement was principally that toward the south by the stronger northern fauna, and representatives of practically all the higher mammals of North America later Tertiary—the horses, mastodons, cats, dogs, camels, tapirs, etc.—overran South America. Some of them have since become extinct in North America, for example, the Camelidae and Tapiridae, but have continued to live on in their new South American home. The northern movement in South America forms introduced some of the gigantic ground-sloths and armadillos temporarily into what is now the region of the United States, their remains being found in several places, in California among others.

The effect of this movement was *firstly* to extend the area occupied, thereby increasing the chances for variation, also the chances for longer survival of those species not well suited in their original environment. In the *second place*, the movement resulted in throwing together two faunas which had not been in competition before, and the result was the partial destruction of the weaker. The South American region has lost its characteristic ungulates and larger edentates, their places being taken by the North American ungulates.

In the third class, an example of a movement which has apparently induced an absolute advance in the life of a particular region by *topographic* and *climatic* changes is the uplift of the Rocky Mountain and plains regions at the end of the Cretaceous time. During the Mesozoic this region was under water or formed largely low-lying plains or swamp country. It was inhabited by numerous large and powerful reptiles, and for a part of the time by a very few insignificant mammals. At the close of the Mesozoic this area was very considerably elevated, and undoubtedly the elevation with subsequent erosion produced a more or less rugged topography in places. The crustal movement producing this topographic change was accompanied by an important organic change, as the reptilian fauna gave way to rapidly developing mammals. The low-lying swamp land of the later Mesozoic would be a favorable environment for reptiles, while the dry, rugged, elevated region would be less favorable for them. In the case of the mammals this change would have the reverse effect.

If crustal movements had not been frequent in the past the evolution of land forms would have been very slow. If at any period in past geologic time oscillation of the earth's surface had ceased absolutely, and the crust had become perfectly stable, what would have been the result? Erosion would in time have cut the land down almost to sea level, the diversity of topography would have been greatly reduced. The climatic conditions would also have become much more uniform. There would have been a leveling of the faunas existing on the continent, perhaps some of the upland forms disappearing entirely. In short, under these conditions, the tendency toward uniformity in the topography, climate and general environment would be reflected to a considerable extent in the fauna. For a time, owing to the throwing together of faunas of different provinces on the continent, the struggle for existence would be more severe than it had been before and perhaps fitter forms than had previously existed would survive this strife. After attaining physical uniformity progress would be relatively slow.

Influence of Crustal Movement on Life of the Sea.—In general, crustal movements have had much less effect upon the sea life than upon land forms. The sea is so large and so deep and its parts so closely connected that a movement which would greatly change the land has relatively little effect upon the sea or upon the habitat and distribution of its inhabitants.

Recently Professor T. C. Chamberlain has called attention to the importance of the submarine continental shelf surrounding most land masses. It is on this continental shelf that most of the more vigorous marine life belonging to the benthos or bottom fauna is found.

In elevation of a land area, or in the withdrawal of the sea, the ocean-covered portion of the continental shelf would become narrower and narrower, the life more and more crowded, and competition more severe. The limit would be reached when the shoreline passed over the edge of the shelf and moved down its steep slope. There would always be a narrow belt of the bottom habitable to shore forms, so that extinction of the whole fauna could not result. Some weak forms would doubtless succumb, and a few strong ones would possibly gain by the competition (survival of fittest).

In case of a subsidence following an elevation the amount of available sea-bottom would be largely increased and the fauna would expand. We would have evolution of another kind, dependent on wealth of opportunity rather than on excessive competition. In the case of crustal oscillations, the conditions mentioned would be in the proper relation to each other to produce the best results; expansion and contraction alternating.

During the latest geological period sea life has probably progressed very slowly, if at all. Marine life seems to have reached a certain level and then stopped so far as progressive evolution is concerned. Possibilities of life in water, on land and in air. Is there another possible environment?

Evolution may in a very general way be referred to as progressive, specialized, and successional. Progressive evolution follows a line of advance in general efficiency and intelligence of the organism. Specialized evolution follows a line of advance in a special feature. Successional evolution is seen in continuously changing series of species in which little if any advance is shown in the successive stages. (Progressive specialization, intensive specialization, indefinite variation.)

Conclusions.—It looks as if the oscillations of the earth's crust must be considered as indirectly among the most important factors in causing changes in the life of the earth. Together with variation in temperature and the development of climatic zones, they have furnished a large portion of the stimulating influence that has carried the organic world to its present advanced stage. They are the occasion but not the cause. It is as if advance in life were in a measure dependent on a pulsation of the earth, which means change, growth, advance. Dead earth, live earth.

Palaeontologic Evidence Regarding History of Climate

Evidence as to climatic conditions in past periods is obtained largely from a study of the nature and distribution of organisms. Important evidence from inorganic geology, as the indication of existence of ice, also available.

Not all organisms valuable as indices of climate. Distribution of some forms limited by *incidental* or superficial characters, e.g., hairy elephant of Siberia and naked elephant of tropics. Other forms limited by *constitutional* features: reef-building corals all sharply limited by temperature.

In general the northern range of southern or warm-climate organisms is limited by the total amount of heat available during the growing period. The southern range of northern forms is fixed by the highest temperature of the hottest days.

Climate of past periods determined: (1) By the presence of forms related to existing organisms known to be constitutionally limited in their adaptation to climates. (2) By the extent of distribution of organisms. Wide distribution generally means uniform climatic conditions. Zonal distribution is often strongly indicative of arrangement of climatic zones.

Wide distribution of reef corals and large, tender plants in Carboniferous time indicates warm even temperature over the earth. Zonal distribution of the protozoan *Nummulites* in Eocene time indicates sharply defined climatic zones, and cooler climate to the north.

Effect of possible cooling of the earth from a higher temperature in stimulating life and increasing activity.

Effect of development of climatic zones producing temperature provinces; effect of the migration of zones from poles to equator in a gradual cooling of the earth.

Reference:

Schuchert, Charles, Climates in Geologic Time. Carnegie Publication 192, pp. 263–298, 1914.

EVOLUTION OF SELECTED GROUPS ILLUSTRATING IMPORTANT PALAEONTOLOGIC PRINCIPLES

History of vertebrates where available gives the most valuable information; as these forms are very complex, they show greater and more rapid changes than the invertebrates, and the variations are generally more easily understood. History of vertebrates known principally from epicontinental formations, which do not accumulate to such an extent as marine deposits, and being above sea-level are easily worked over and redeposited.

Invertebrates, particularly marine forms, more abundant than vertebrates; their history at present more nearly complete than that of the vertebrates. The evolution of these forms generally furnishes less information than that of the vertebrates, but more material is actually available at the present time.

History of Foraminifera

- Protozoa—unicellular
  - Rhizopods
    - Monera?
    - Amoeba
    - Foraminifera
    - Radiolaria and others
  - Infusoria and other forms
- Metazoa—many-celled

Foraminifera, the simplest or most primitive animals possessing skeletons which could be preserved as fossils. If the highest life is derived by a process of modification from the lowest, then the lowest should be the oldest. Foraminifera should therefore be expected among the oldest fossils. They are actually found—radiolaria also—all through the rock systems down to pre-Cambrian formations. The earliest forms differ but little from those now living. This is in accordance with the law that simple forms change slowly.

Taking the history of the foraminifera in the broadest sense, we find that such changes as have occurred in the group are in accordance with the law that the most specialized forms occur last. *Fusulina*, a fairly specialized form, occurs in the Carboniferous. *Nummulites*, one of the most specialized groups, occur in the Eocene. Near living relatives of the Eocene form are rare.

Reference:

Huxley, T., The Story of a Piece of Chalk. Huxley Essays.

Evolution of Pelecypoda

Earliest forms without neck or siphon. Siphonates appear in Carboniferous and increase in importance to present day. The most highly specialized siphonates are the boring shells like Teredo and similar types.

Pelecypods, rare in early Palaeozoic, common in early Mesozoic. Maximum of group now past.

The peculiarly specialized *Hippurites* of late Cretaceous developed out of a Jurassic form with valves much like those in ordinary pelecypod, excepting for elongation of the beaks.

Evolution of Cephalopoda

Oldest known form *Orthoceras* in upper Cambrian. The series of forms in the line of evolution of those types which retained the shell is as follows:

Cambrian *Orthoceras*, straight shell, straight suture, central siphon, anteriorly concave septum, posterior siphonal collar (partition = septum; edge of partition = suture; central opening in partition = siphonal opening; projection of partition around siphonal opening = siphonal collar).

Cambrian (later than *Orthoceras*) *Cyrtoceras*, shell same as *Orthoceras*, but slightly curved.

Ordovician *Nautilus*, shell coiled, suture slightly curved, otherwise as in *Orthoceras*.

Silurian *Goniatites*, shell coiled, suture zigzagged, siphon external.

Carboniferous *Ammonite group*. Shell coiled, suture very complex, siphon external, septum concave backward, siphonal collars pointed forward.

Cretaceous ammonites show many uncoiled forms; most extreme types *Baculites*, straight, coiled only in very young stages.

Maximum of nautilus group Silurian—were then dominant animals of earth (age of molluscs). Maximum of goniatites in Carboniferous. Maximum of ammonites in middle Mesozoic. Maximum of groups in order of complexity of shell structure.

Simple nautilus still living, though very rare. Goniatites disappeared in Carboniferous. Ammonites disappeared in Cretaceous.

Each ammonite repeats in its individual history (ontogeny) the principal stages passed in the history of the race (phylogeny). The smaller inner coils of the shell represent a form much like a goniatite or a nautilus; in successive coils the shell gradually takes on the more complex characters of the ammonite. The *recapitulation* (repeating of phylogenic stages in the ontogeny) shown in this group is one of the most remarkable cases known.

Nautilus and allies possessed four gills (tetrabranchiates). Squid and allies descended from it have two gills (dibranchiates). *Belemnites* of the Mesozoic is a typical dibranchiate showing relationship both to the recent cuttlefish and to *Orthoceras*, from which the *Belemnites* is descended. Shell of belemnite: (1) A chambered shell (phragmocone) much as in *Orthoceras* (siphon lateral instead of central). (2) Edge of mouth opening of shell projects on one side as a broad blade or spoon (pro-ostracum). (3) Around the chambered shell and extending beyond the point a secondarily secreted spike (rostrum). Nearly the whole shell was embedded in the body, the pro-ostracum protecting the back, the rostrum possibly projected through the skin. This form of belemnite shell is a modified *Orthoceras*. Triassic belemnite had relatively larger phragmocones than Cretaceous forms.

The cuttlefish is derived from *Belemnites* by reduction of rostrum and phragmocone, and increase in size of the protecting pro-ostracum. The active and intelligent *Octopus* has lost all internal skeleton. This series begins with the protected *Orthoceras* and ends with unprotected but active and intelligent *Octopus*.—Intelligent and active forms always triumph over those depending on armor for protection.

Reference:

Smith, J. P., Evolution of Fossil Cephalopoda. In Jordan, D. S., Footnotes to Evolution, 1898, pp. 229–255.

Evolution of the Horse

The modern horse is a highly specialized animal, particularly in the structure of its feet and teeth. It possesses but one toe on each foot and stands upon the tip of the terminal toe joint. Its teeth are virtually of two kinds instead of four. The chisel-like front teeth are removed quite a distance in the jaw from the broad, prismatic cement-covered grinders. The grinders continue to grow up from the root as they are worn off at the crown. The earliest known horses, occurring in Eocene, were small animals about as large as a hound. They had four functional toes on the front feet and three on the hind feet. The teeth were of four kinds, the front teeth were less distinctly chisel-like than now, and the nose was shorter. The back teeth were short-rooted, did not show continued growth as they were worn away. They were not broad prismatic, and had no cement on the crown.

In Miocene time the descendants of the Eocene horses had grown larger, the feet had not more than three toes on each foot, and the side toes were rarely functional. The teeth were in structure about half way between those of the Eocene horse and those of the existing ones.

From Eocene to the present a practically continuous series can be traced in structure of feet and teeth. In fact, all parts of the skeleton show a gradual modification of the animal tending toward the present form. This series is well known from a large number of specimens. The modification has tended to produce a larger and more intelligent animal, which has developed more slender and elastic limbs, and a dentition better suited for subsistence on a purely vegetable diet.

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H. F. Osborn, Evolution of the Horse in America. Century Magazine, November, 1904, p. 3.
F. A. Lucas, Animals of the Past, chap. 9.
W. H. Flower, The Horse.
R. Lydekker, The Horse and Its Relatives.
W. D. Matthew, The Evolution of the Horse. Guide Leaflet Series, Am. Mus. Nat. Hist., No. 36.

Evolution of the Elephant

The elephant group includes some of the largest and most specialized of land mammals. The group has had a wide geographical distribution and a long history. It probably originated in Africa in Eocene time.

Existing elephants have rather generalized feet with five toes. The dentition is reduced to one immense grinding tooth in each jaw at a time and two large upper incisors modified as tusks and without enamel covering. The grinders possess a great number of thin plate-like elevations on the crown (as many as 27) and the spaces between the plates are filled with cement. The grinders belonging in the jaw come in one at a time and the teeth are thus renewed many times. This is much to the advantage of a long-lived animal. The development of the great trunk has caused a thickening of the skull to give increased external skull surface for support of the muscles.

Eocene elephants small; complete sets of upper and lower teeth were present together, not single teeth alone. Tusks very short, inconspicuous and enamel-covered. Other incisors are also present in both upper and lower jaws. Back teeth, six in number, and each with four small tubercles or prominences much as in human teeth. Probably a small proboscis present much as in the living tapir. Earliest form *Moeritherium*. *Palaeomastodon* with better developed tusks not accompanied by other incisors, larger back teeth with the outer and inner tubercles tending to form several cross-ridges.

The middle Cenozoic (Miocene) *Mastodon*, larger animal with larger tusks (which may be present in both upper and lower jaws); fewer back teeth, but with larger individual teeth on which as many as six pairs of tubercles or cross-ridges may be present. Enamel on tusks nearly gone. In the earlier mastodons as the upper tusks elongated the growth of the trunk kept pace.

In the late Cenozoic (Pliocene) a large proboscidean, *Stegodon*, without lower tusks, and without enamel on the upper tusks, presents a transition from mastodon to elephant. The back teeth were reduced in number, one or two at one time. The pairs of tubercles formed high cross-plates (as many as 13) between which cement accumulated in considerable quantity.

The gap between *Stegodon* and *Elephas* (Elephant) in the Pliocene and Pleistocene is filled with several forms which might be referred to either group, just as *Stegodon* has sometimes been called a mastodon and sometimes an elephant.

The history of this group shows a gradual increase in size, loss of all but two upper incisors, loss of enamel on the incisors, increase in size and complexity of the molars, reduction of number of molars in jaw at one time, development of the proboscis, and other hardly less peculiar characters.

The earliest forms seem to have been remarkably variable in size, and have therefore given natural selection an exceptional opportunity to develop a group of large individuals.

References:

H. F. Osborn, Hunting the Ancestral Elephant in the Fayum Desert. Century Magazine, October, 1907, p. 815.

E. R. Lankester, Extinct Animals, pp. 90–132.

F. A. Lucas, Animals of the Past, chaps. 10 and 11.

R. S. Lull, The Evolution of the Elephant. Ann. Rept. Smith. Institution, 1908, pp. 641–675.

Human History from the Point of View of the Palaeontologist

The results of a study of the early history of the human family by natural history methods.

Nature of the human race today, considered from point of view of the *biologist.* Widely differing physical types. The physical characters as different as those of different species of other kinds of organisms. The different physical types were originally in different geographic regions.

Judging by what we know of the evolution of many other kinds of organisms, the extent of physical variation and the geographic distribution of the different human types indicate the following points with reference to the history of the race:

(*a*) It has been in existence longer than a geological epoch. (Judging by the rate of differentiation compared with that of other creatures, which is known approximately.)

(*b*) It is not probable that any existing form of man is the original or primitive type. (Species of the higher groups of animals last a comparatively short time.)

(*c*) The Old World is probably the place of origin of man. (Human type in America shows little differentiation over a wide area, and has presumably not lived on this continent long enough to have experienced much variation. Old World types have presumably lived for a long period while the variation was taking place.)

The human race considered as a physical group is presumably subject to the same laws of variation or evolution that have influenced other organic forms.

Illustration of most primitive types of human race of present period. (Tasmanian, Bushman, Veddah.)

Early History of Man.—Human history based largely on stages of culture. Age of metal-working; age of stone.—Historic period falls within the limits of age of metals. Stone age precedes metal age at all places in the world where man is found to have existed for more than a few thousand years.

History of stone age not studied by written records. Methods of archaeologist, palaeontologist. Succession of strata or layers is really the fundamental criterion for judging successive or relative age.

Stone age	Neolithic	Polished or rubbed implements Chipped or flaked implements
	Palaeolithic	Chipped or flaked instruments only
	Eolithic	Stones intentionally pounded, battered or roughly flaked by man in order to produce an artificial edge

The neolithic stage precedes and grades into the age of metals in Europe. During this epoch physical conditions in Europe were not different from those of the present day. The animal and plant species were also similar to those of the present. Neolithic epoch is a part of the Recent, or present, geological period.

The palaeolithic stage of development immediately precedes the Recent geological period. In many parts of the world, particularly in Europe, skeletal remains of man associated with numerous objects evidently fashioned by him for a definite purpose are found in stream deposits and in accumulations in caves, in such situations as to leave no doubt that they were buried in an earlier geological time than the present or Recent period. The evidence of age is shown in several ways.

(*a*) Remains found in stream deposits on terraces far above the present valley floor. Since the streams flowed at the level in which the terrace deposits were formed, great movements of the land have occurred; the whole region has been elevated and streams have cut new and deeper channels. The movements of the earth's crust concerned in this change are known to have modified the geography of the earth considerably, and the time preceding them is separated from the Recent period.

(*b*) The remains of animals and plants found associated with the human remains and implements in these ancient deposits are very largely those of forms no longer existing on the earth. Of those which have lived on to the present day, a large percentage are found only in regions widely separated from the place in which the fossil remains are found.

In brief, the physical features of the earth's surface, the climatic conditions and the life have very greatly changed since some of the more ancient peoples of the earth became extinct.

The stone implements found in the latest strata formed before the present period are chipped or flaked. The typical neolithic culture is not known to extend back to this period. This period, the palaeolithic epoch or stage, belongs in the geological period immediately preceding the present, that is, in the Pleistocene period.

Physical conditions in Europe during Pleistocene. Somewhat different distribution of land and sea. Glacial and interglacial periods. Fauna underwent several quite radical changes—mammoth or woolly elephant, woolly rhinoceros, extinct cave bear, extinct cave lion, extinct cave hyaena, extinct horse, etc., were contemporary with early man.

History of palaeolithic man best known in Europe. In southwestern France, in the Dordogne region, remains are particularly abundant. Probably the region furnished a favorable place in which to live in palaeolithic time and conditions have been very favorable for preservation of the remains since that epoch.

Caves of La Madeleine, Laugerie Haute, Combarelles, Font de Gaume.—Skeletal remains, not widely different from those of modern man; stone implements (Magdalenian flints), bone and antler implements; ornaments, drawings, carvings; use of fibre; needles and clothing; associated animals, reindeer, mammoth, cave bear, bison.

Caves of Le Moustier, Chapelle-aux-Saints, Spy, Neanderthal.—Skeletal remains, small brain, type very different from any existing type of man; stone implements (Mousterian flints); other evidences of workmanship rare; use of fire. A type of being undeniably belonging in the human family, making implements and using fire, yet distinctly lower than the lowest race now in existence.

Stream-terrace deposits still older than Le Moustier and with artificially chipped flints of a rougher or more primitive type. Chellean division of palaeolithic.

Principal divisions of Palaeolithic epoch	Magdalenian division
	Mousterian division
	Chellean division

The eolithic stage, early Pleistocene or Pliocene. In still older deposits than those of the Chellean stage, in a few localities numerous fractured flints have been found on which the fractures seem hardly of the kind that would be formed by any natural process.—*Eoliths.*

According to any theory of evolution by which we might wish to account for the appearance of the works of primitive man, there should be an early stage in which man's intelligence first directed him to use as implements such objects as happened by virtue of their natural form to suit themselves to his hands. Oval pebbles would be among these objects. Perhaps by chance a flint pebble was fractured in use. After this had occurred repeatedly, pebbles were intentionally fractured to form sharp points or edges. A long period would pass before the developing intelligence became capable of directing the breakage on flint pebbles so as to make a definite type of fracture, different from that caused in nature. The implements of this stage would be eoliths.

Skeletal remains of eolithic epoch. Heidelberg men in beds of Pliocene (?) age—period preceding Pleistocene. *Pithecanthropus* of Java, Pliocene—a lower type than Mousterian man, skull small, limbs indicate that the creature stood erect. A missing link.

Pithecanthropus and Heidelberg man within the Hominidae or man family. They stood erect and the anterior limbs were free to serve the head. Brains were relatively larger than in other animals. (*Erect position; hands free to serve head; brain large.*) They differ from Recent man in their vastly lower grade of intelligence and inferior level of culture.

The history of the human family shows a rate of evolution corresponding in a general way to that of other organic types.

The important lesson of this discussion is not how far down in the scale we have been, but how far up we have come.

If the human race does not advance beyond the present level it will apparently be owing to a special weakening or lack of vitality at this particular stage. The ape man of Eolithic time, the bestial man of Le Moustier, and the hunters of La Madeleine did their part in advancing intelligence and cultural stages. What may we expect of the present, and what of the future?

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Morris, Charles, Man and His Ancestors.
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GEOLOGY

THE GEOLOGIC RELATIONS OF THE MARTINEZ GROUP OF CALIFORNIA AT THE TYPICAL LOCALITY

THE term "Martinez Group" was first used by W. M. Gabb in his classification of the Cretaceous of California,[1] the group of strata provisionally so designated being considered by him as standing between the Chico of his Cretaceous A and his Tejon or Cretaceous B. The Martinez was said to be of small geographical extent and to bear such a relation to the Chico that future investigation might show it to be a part of that group. About sixty species were listed by Gabb from the group, most of them having been collected near the town of Martinez, in Contra Costa county.

For a number of years after the publication of the second volume of Gabb's work on the palæontology of California, the Martinez group was scarcely mentioned in geological literature, probably because, as described by him, it was not well understood. However as the Cretaceous B or Tejon came to be generally considered as Eocene the importance of the group, as a possible connecting link between the Chico-Cretaceous and the Tejon-Eocene, became evident.

In a recent publication[2] by Mr. T. W. Stanton the fauna and stratigraphy of a number of the most important of Gabb's Martinez localities have been clearly discussed and a complete reorganization of the hitherto heterogeneous group effected. Mr. Stanton has shown the Martinez of Gabb to consist of two parts, one characteristic Cretaceous and inseparable from the Chico group, the other being more closely related faunally and stratigraphically to the Tejon-Eocene than to the Chico. The upper portion was therefore

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[1] See Rep. Geol. Surv. of Cal. Palæontology, Vol. II, p. 13 of Preface. Gabb divided his Californian Cretaceous into a lower division, A, including the Shasta, Chico, and Martinez (?), and an upper division, B, or the Tejon. His Cretaceous B is now generally regarded as Eocene.

[2] The Faunal Relations of the Eocene and Upper Cretaceous on the Pacific Coast, 17th Ann. Rep. U. S. Geol. Survey, 1895–6.

placed with the Tejon and designated as Lower Tejon. As a possible modification of his classification Mr. Stanton states that, "if more detailed field work makes it desirable to retain the name (Martinez) at all, it should be restricted to the Eocene (upper) portion. . . ."

In the following discussion the name Martinez is applied to that portion of Gabb's Martinez group which remains, after the removal of the Chico-Cretaceous element. The writer's statements are based on observations, extending over a period of several years, made in the typical region for the group, viz., that adjacent to the town of Martinez.

In the hills to the southwest of Martinez strata of unquestioned Chico age, containing a characteristic fauna, occur over a considerable area. In a fine outcrop of compact, bluish sandstone occurring on the west side of Alhambra Valley, and near the top of the Chico, the writer found an abundance of fossils, characteristic of this group, which are listed in the table below, under Locality No. 1. From this point to the east and west the structure of the strata is anticlinal, showing an apparently conformable series up as far as the Miocene on each side.

From the standpoint of stratigraphy, one would hardly be disposed to find fault with Gabb's conception of the Martinez, since in this, the typical locality, the Chico, Martinez, and Tejon, *appear* everywhere to be conformable, while numerous complications of the stratigraphy have still farther increased the difficulty of separating these three groups on stratigraphic grounds.

Lithologically there are some differences between the Martinez and the adjoining formations, the most important of which are the slightly different aspect of its sandstones and the frequent presence in them of considerable quantities of glauconite. The sandstones are often grayish, differing from the yellowish or bluish rocks of the Chico and the massive white to dull red Tejon sandstones. In many places the Martinez contains large quantities of glauconite disseminated evenly through the sandstones in rounded grains of considerable size. Glauconite does not seem to occur at all in the Chico but may possibly be found toward the base of the true Tejon. The truly glauconitic rocks belong principally to the Martinez.

While the group shows little which would serve to separate it stratigraphically or lithologically from the over and underlying

TABLE SHOWING CHANGES OF FAUNA FROM CHICO TO TEJON[3]

	Chico	Martinez	Tejon
LOCALITY No. 1.—TYPICAL CHICO			
1 *Corbula cultriformis* Gabb...	*		
2 *Meekia sella* Gabb.........	*		
3 *Meekia navis* Gabb.........	*		
4 *Meretrix arata* or *fragilis* Gabb..................	*		
5 *Mytilus quadratus* Gabb....	*		
6 *Mytilus pauperculus* Gabb..	*		
7 *Nucula truncata* Gabb......	*	*	*
8 *Pecten martinezensis* Gabb..	*		
9 *Pectunculus Veatchi* Gabb...	*		
10 *Tellina Hoffmanniana* Gabb.	*		
11 *Tellina aequalis* Gabb (?)...	*		
12 *Venus varians* Gabb........			
13 *Cinulia obliqua* Gabb.......	*		
14 *Cylindrites brevis* Gabb (?)..	*		
15 *Dentalium Cooperi* Gabb....	*	*	*
16 *Gyrodes expansa* Gabb......	*		
17 *Perissolax brevirostris* Gabb n. var..................	*		
18 *Pugnellus hamulus* Gabb....	*		
19 *Solarium inornatum* Gabb...	*		
20 *Helicoceras vermicularis* Gabb..................	*		
21 Sharks' teeth 2 sp..........	*		
22 Teleost fish scale..........			
LOCALITY No. 2.—LOWER MARTINEZ			
1 *Flabellum Remondianum* Gabb..................		*	*
2 *Placosmilia* n. sp...........		*	
3 *Schizaster* (?) n. sp.........		*	
4 *Arca* n. sp.................		*	
5 *Cardium Cooperi* Gabb.....		*	†
6 *Cucullæa Mathewsoni* Gabb.		*	
7 *Leda Gabbi* Conr...........		*	*
8 *Lucina* sp.................		*	
9 *Meretrix* sp................		*	
10 *Modiola* n. sp.............		*	
11 *Pholadomya nasuta* Gabb....		*	
12 *Tapes quadrata* Gabb (*aff.*)..		*	*
13 *Tellina* n. sp...............		*	
14 *Actaeon* (?) n. sp...........		*	
15 *Cylichna costata* Gabb......		†	*
16 *Dentalium Cooperi* Gabb....	*	*	*
17 *Discohelix* n. sp...........		*	
18 *Fusus* n. sp. (*a*)...........		*	
19 *Fusus* n. sp. (*b*)...........		*	
20 Indet. nov................		*	
21 *Neptunea mucronata* Gabb..		*	
22 *Perissolax Blakei* Conr. n. var.....................		*	
23 *Siphonalia lineata* Stanton..		*	
24 *Turritella* sp..............		*	
25 *Urosyca caudata* Gabb......		*	
26 *Urosyca* n. sp.............		*	
27 *Xenophora* n. sp...........		*	
28 Glauconite................			
29 Foraminifera..............			
LOCALITY No. 3.—UPPER MARTINEZ			
1 *Arca* n. sp................		*	
2 *Cardium Cooperi* Gabb.....		*	†
3 *Cucullæa Mathewsoni* Gabb.		*	
4 *Leda Gabbi* Conr..........		*	*
5 *Modiola ornata* Gabb.......		†	*
6 *Pholadomya nasuta* Gabb...		*	
7 *Solen* n. sp................		*	
8 *Tellina* (?) *undulifera* Gabb..		*	
9 *Brachysphingus liratus* Gabb.		*	
10 *Bullinula* (?) n. sp.........		*	
11 *Dentalium Cooperi* Gabb....	*	*	*
12 *Fusus* n. sp...............		*	
13 *Heteroterma Gabbi* Stanton..		*	
14 *Perissolax Blakei* Conr. n. var.....................		*	
15 *Siphonalia lineata* Stanton...		*	
16 *Strepsidura pachecoensis*, Stanton................		*	
17 *Turritella infragranulata* Gb.		*	
18 *Urosyca caudata* Gabb......		*	
LOCALITY No. 4.—NEAR UPPER LIMIT OF MARTINEZ			
1 Nummuloid...............		*	
2 *Schizaster* (?) n. sp.........		*	

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[3] An asterisk indicates common or characteristic; a dagger, rare or characteristic of some other horizon.

TABLE—*Concluded*[4]

	Chico	Martinez	Tejon		Chico	Martinez	Tejon
LOCALITY No. 4.—NEAR UPPER LIMIT OF MARTINEZ—*Concluded*				LOCALITY No. 5.—TEJON, A SHORT DISTANCE ABOVE LOCALITY No. 4			
3 *Cardium Cooperi* Gabb.....		*	†	1 *Trochosmilia striata* Gabb...			*
4 *Cardita Hornii* Gabb.......		†	*	2 *Cardium Breweri* Gabb......			*
5 *Modiola* n. sp.............		*		3 *Cardium Cooperi* Gabb.....		*	†
6 *Solen* n. sp................		*		4 *Cardita Hornii* Gabb.......		†	*
7 *Tellina Hornii* Gabb.......		†	*	5 *Meretrix Hornii* Gabb......			*
8 *Tellina* n. sp..............		*		6 *Meretrix uvasana* Conr......			*
9 *Thracia* (?) n. sp..........		*		7 *Modiola ornata* Gabb.......		†	*
10 *Ampullina striata* Gabb (*conf.*)..................		*		8 *Nucula truncata* Gabb......	*	*	*
11 *Dentalium stramineum* Gabb.	*	*	*	9 *Pectunculus sagittatus* Gabb.			*
12 *Ficopsis* sp. (near *Remondi*)..		*	*	10 *Amauropsis alveata* Gabb...			*
13 *Megistostoma striata* Gabb..		†	*	11 *Cylichna costata* Gabb......		†	*
14 *Morio* sp. (*tuberculatus?*)....		†	*	12 *Conus Remondi* Gabb......			*
15 *Solarium* n. sp............		*		13 *Dentalium Cooperi* Gabb....	*	*	*
16 *Tritonium* n. sp............		*		14 *Ficopsis Remondi* Gabb.....			*
17 *Tritonium* (?) n. sp.........		*		15 *Ficopsis* sp. (near *Remondi*)..		*	*
18 *Turris* n. sp...............		*		16 *Morio* sp. (*tuberculatus*).....		†	*
19 *Turritella* n. sp. (?)........		*		17 *Perissolax Blakei* Conr. Typ. var....................			*
				18 *Rimella canalifera* Gabb....			*
				19 *Turritella uvasana* Conr.....			*
				20 *Oliverato californica* Cooper..			*

formations, its fauna, on which Gabb based his classification, contains numerous elements throwing light on its geologic relations. Between the Chico-Cretaceous and the Miocene there are two distinct faunas present, viz., the Martinez (in part) and Tejon of Gabb, or the Lower and Upper Tejon of Mr. Stanton. As other criteria failed to separate satisfactorily the Chico, Martinez, and Tejon, extensive fossil collections were made by the writer at all possible points. A series of rich localities running across the strike from the Chico to the Tejon furnished the sequence of faunas as shown in the table on pages 1765 and 1766.

An examination of these lists shows that the lower Martinez beds, as stated by Mr. Stanton, have a fauna distinct from that of the Chico, and that, while the two sets of rocks may seem to be conformable, an unconformity, as yet unobserved, probably exists. There are no species common to localities 1 and 2 excepting *Dentalium Cooperi* which ranges up into the Tejon and appears to be identical with a form occurring in the lowest Miocene. Other localities furnishing a few imperfect fossils are known in beds perhaps somewhat lower down than Locality No. 2 but as yet no distinct overlapping of the two faunas has been discovered.

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[4] An asterisk indicates common or characteristic; a dagger, rare or characteristic of some other horizon.

Locality No. 3, higher up in the group, furnishes a fauna of the same type as that of No. 2 but containing some forms as *Tellina* (?) *undulifera*, *Turritella infragranulata*, and *Brachysphingus liratus*, not present in the lower beds. One minute specimen of the characteristic Tejon form, *Modiola ornata*, was obtained at this horizon.

At Locality No. 4, near the upper limit of the Martinez, about one third of the fauna is composed of species known from the Tejon. Of these forms *Dentalium stramineum* is a long-lived species ranging from Chico to Tejon. *Cardium Cooperi*, though known from Tejon beds, is not a common or characteristic fossil of that group, while it ranges through the Martinez and is one of its most characteristic species. The *Cardita* belongs to the Tejon species described as *Hornii* by Gabb but may be a new variety. *Megistostoma striata*, *Tellina Hornii* and the *Morio* seem to be typical Tejon forms and are not found below the uppermost beds of the Martinez. The *Ficopsis* sp. is a form known from the Upper Martinez and Lower Tejon. Imperfect specimens of a foraminifer related to *Nummulites* are abundant at this locality. Though the fauna at this horizon is certainly closely related to that of the true Tejon, only three good species are common or characteristic forms in that group.

At Locality 5, a short distance (less than 100 feet) above No. 4, fossils of the well-marked fauna to which Gabb gave the name Tejon are found in abundance, *Cardium Cooperi* being the only really characteristic Martinez species associated with them. No localities showing more gradation between the Martinez and Tejon faunas than those here discussed have so far been discovered by the writer.

Numerous other collections made between Localities 2 and 3 and between 3 and 4 furnished gradations from one to the other, with some additional species not mentioned in the foregoing lists.

In the following table there are placed together all of the species known to the writer from the strata between the Chico and the true Tejon near Martinez, along with those which have been collected

THE FAUNA OF THE MARTINEZ GROUP WITH GEOLOGICAL RANGE OF THE SPECIES[5]

	Chico	Martinez	Tejon
1 Foraminifera Nummuloid...		*	
2 Foraminifera 3 sp. Indet....			
3 *Flabellum Remondianum* Gabb..................		*	*
4 *Placosmilia* n. sp...........		*	
5 *Schizaster* (?) n. sp.........		*	
6 *Terebratulina tejonensis* Stanton................		*	
7 *Arca* n. sp.................		*	
8 *Cardita Hornii* Gabb.......		†	*
9 *Cardium Cooperi* Gabb.....		*	†
10 *Crassatella unioides* Stanton.		*	
11 *Cucullæa Mathewsoni* Gabb..		*	
12 *Leda alæformis* Gabb.......		*	
13 *Leda Gabbi* Conr...........		*	*
14 *Lima multiradiata* Gabb....		*	
15 *Lucina Turneri* Stanton....		*	
16 *Meretrix* sp...............		*	
17 *Modiola* n. sp..............		*	
18 *Modiola ornata* Gabb.......		†	*
19 *Nucula truncata* Gabb......	*	*	*
20 *Pectunculus Veatchi* var. *major* Stanton...........		*	
21 *Pholadomya nasuta* Gabb....		*	
22 *Plicatula ostreiformis* Stanton....................		*	
23 *Solen* n. sp................		*	
24 *Tapes quadrata* Gabb (*aff.*)..		*	*
25 *Tellina* n. sp..............		*	
26 *Tellina Hornii* Gabb.......		*	*
27 *Tellina* (?) *undulifera* Gabb..		*	
28 *Teredo* (?)................			
29 *Thracia* (?) n. sp..........		*	
30 *Actaeon* (?) n. sp..........		*	
31 *Ampullina striata* Gabb (*conf.*)..................		*	
32 *Brachysphingus liratus* Gabb		*	
33 *Bullinula* (?) n. sp.........		*	
34 *Cylichna costata* Gabb......		†	*
35 *Dentalium Cooperi* Gabb....	*	*	*
36 *Dentalium stramineum* Gabb.	*	*	*
37 *Discohelix* n. sp...........		*	
38 *Ficopsis* sp. (near *Remondi*)..		*	*
39 *Fusus* n. sp (*a*)...........		*	
40 *Fusus* n. sp. (*b*)...........		*	
41 *Heteroterma Gabbi* Stanton...		*	
42 *Heteroterma striata* Stanton..		*	
43 *Heteroterma trochoidea* Gabb.		(?)	
44 Indet. nov................		*	
45 *Lunatia Hornii* Gabb.......		†	*
46 *Megistostoma striata* Gabb...		†	*
47 *Morio* sp. *tuberculatus?*......		†	*
48 *Natica* sp.................			
49 *Neptunea mucronata* Gabb...		*	
50 *Perissolax Blakei* Conr. nov. var.....................		*	
51 *Siphonalia lineata* Stanton..		*	
52 *Solarium* n. sp............		*	
53 *Stripsidura pachecoensis* Stanton................		*	
54 *Tritonium* n. sp. (*a*)........		*	
55 *Tritonium* (?) n. sp. (*b*).....		*	
56 *Turbinella crassitesta* Gabb..		*	
57 *Turritella infragranulata* Gabb..................		*	
58 *Turritella pachecoensis* Stanton.....................		*	
59 *Turritella* n. sp. (?)........			
60 *Turris* n. sp..............		*	
61 *Urosyca caudata* Gabb......		*	
62 *Urosyca* n. sp.............		*	
63 *Xenophora* n. sp...........		*	
64 Crustacean remains, brachyuran..................		*	
65 Crustacean remains, macruran....................			
66 *Serpula*..................			

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[5] An asterisk indicates common or characteristic; a dagger, rare or characteristic of some other horizon.

elsewhere by Mr. Stanton, in beds of the same age. A study of this list shows clearly that the fauna is a unit, and that it is quite distinct from both the Chico and the Tejon, though it grades to some extent into the latter.

The existence between the Chico and the Tejon of a fauna not belonging clearly to either group was evidently not unknown to Gabb, and this fauna formed the real basis of his Martinez. Unfortunately the involved stratigraphy led him or his collectors into the error of supposing that certain Chico forms belonged in the same horizon with Martinez species, while the first error led to a second, viz., the belief that, since Chico forms were present in his Martinez fauna, the whole group might be found later to represent a subdivision of the Chico. As has been shown in the comparison of faunas, there can be little doubt that the Chico group is widely separated from what is here called Martinez.

In considering the relations of the Martinez to the Tejon, it might be well to determine first what was intended in the original definition of the Tejon group and what it really is. The name was proposed by Gabb on *palæontological grounds* for a set of rocks, supposed by him to be Cretaceous, but now generally regarded as Eocene, "most extensively developed in the vicinity of Fort Tejon and about Martinez." It was stated[6] to contain "a large and highly characteristic series of fossils, the larger part peculiar to itself, while a considerable percentage is found extending below into the next group, and several species still farther down into the Chico group." Since Gabb's work was published the Tejon has been recognized at numerous points on the Pacific coast, outside the limits of its distribution as known to him, and has always been found to contain an easily recognized fauna, of which a number of the most common and characteristic forms are found in the list of species from locality No. 5. As may be seen in the last quotation, the true relation of the Martinez to the Tejon, as shown by the partial mingling of species, was not unknown to Gabb.

In the vicinity of the town of Martinez, the Martinez and Tejon groups form an apparently conformable series between two and three thousand feet in thickness and about equally divided between the two. The faunas, though overlapping, are in the main quite distinct and no great difficulty has been experienced by the writer in separating the groups on this basis. While some intermingling of species exists, it is not greater than we should expect to find in adjoining groups or periods. It should also be observed that the beds with a Tejon-like Martinez fauna and those containing an assemblage of characteristic Tejon forms are comparatively close together. The change from one fauna to the other may possibly have taken place in a short time by migration, but we cannot assert positively as yet that the apparent conformity of the beds is a real one, sedimentation may have been interrupted between the times of deposition of the two groups. It is at any rate quite clear that the two sets of strata, or two faunas, while belonging perhaps to the same series, represent different periods in the geological history of California, periods quite as distinct, so far as faunal evidence is concerned, as the Miocene and Pliocene, or the Pliocene and Quaternary. The upper division of this series has already, on the grounds of its characteristic fauna, been named the Tejon. To a mixed group of rocks, to which the fauna here called the Martinez gave individuality, the name Martinez group was applied by Gabb. It seems desirable, after having cut out the Chico portion of Gabb's Martinez which was probably not the one on which he based the group, to apply the name used by him to the distinct fauna or group which remains. As to the nomenclature of the supposedly conformable series, including the Martinez and Tejon, it seems best to apply to it for the present the term Martinez-Tejon series, though future convenience may demand a special series name. To apply the name Tejon to the whole series would be to modify considerably the meaning of this term as used originally, and would have besides the fault of taking the name from a smaller division to apply it to a larger, leaving the first to be virtually renamed.

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[6] Rep. Geol. Surv. Cal. Palæontology, Vol. II, p. 13 of Preface.

In conclusion, the group under consideration might be characterized as follows: The Martinez group, comprising in the typical locality between one and two thousand feet of sandstones, shales, and glauconitic sands, forms the lower part of a presumably conformable series, the upper portion of which is formed by the Tejon. It contains a known fauna of over sixty species, of which the greater portion is peculiar to itself. A number of its species range up into the Tejon and a very few long-lived forms are known to occur also in the Chico. Since the Martinez and Chico are faunally only distantly related it is probable that an unconformity exists between them. Though satisfactory correlation of Californian formations with the subdivisions of the standard geological scale can be accomplished only when the local scale is fully worked out, we may, for the present at least, accept Mr. Stanton's correlation of the Martinez with a portion of the Eocene.

Berkeley, California

GEOLOGY IN CALIFORNIA

No branch of scientific work can be successfully carried on without good laboratory facilities. While much of the knowledge that we obtain in all departments of science necessarily comes to us in the form of printed statements of the results of the work of others, the fundamental principles of that branch of learning must be gotten from first-hand observations. In some sciences, as chemistry or physics, much of the material for work may be brought together anywhere, and no one locality has many advantages over another. In other departments, such as biology, free access to sources of living material is necessary, and laboratories like those at Naples have great advantages.

In the group of sciences based upon a study of the earth's crust, the conditions upon which successful investigation and teaching are dependent are still harder to satisfy.

In those regions where the strata of the crust are horizontal, there are generally but few formations to be seen; in mountainous countries where the strata have been crumpled, the edges of a great many rock systems are often exposed. Unlike chemical or physical work, fully satisfactory study and especially investigation in these sciences cannot be carried on upon transported materials; the strata themselves must be examined.

Few universities in the world are as favorably situated with reference to work in these sciences as California and Stanford. Within easy reach of both are crumpled strata, furnishing splendid material for illustration and study; while within working distance are formations representing practically the whole of the geological column from Archaean to Quaternary. Nearly every phase of geological science, from its historical aspect to pure mineralogy, finds not only abundant illustrative material but a wealth of problems for profitable investigation. Just as the wonderful physical environment in which Californians are placed is certain to be reflected in a splendid literature, so the unexcelled advantages for investigations in geological science will naturally stimulate work in this field to a much greater extent than in many other less favored regions.

University of California Magazine, vol. 7, p. 192, May 1901.

SUGGESTED PALEONTOLOGIC CORRELATION BETWEEN CONTINENTAL MIOCENE DEPOSITS OF THE MOHAVE REGION AND MARINE TERTIARY BEDS OF SAN JOAQUIN VALLEY, CALIFORNIA

In the formations of the Mohave region numerous mammalian remains have recently been found. The fauna of the Mohave region is most nearly allied with that of the Upper Miocene formations in the western border of the Great Plains region.

The continental deposits of the Mohave region extend to the foot of the mountain range to the east of Tehachapi. The great marine and fresh-water series of the San Joaquin Valley lies on the west flank of the range only a short distance from the most westerly exposure of the Mohave beds. Recently R. W. Pack has obtained from marine Tertiary beds in the Tejon Hills, on the west flank of the range, a small collection of vertebrate remains. This collection includes the phalangeal elements of *Merycodus*, a small deer-like form, similar to a species known in the Mohave beds, and teeth of a horse similar to *Merychippus calamarius* of the Mohave region. Associated with these remains are shark's teeth and a number of marine shells. The known invertebrate fauna of these beds has been presumed to indicate their Lower Miocene age. The question arises as to whether the mammal-bearing beds of the eastern border of the San Joaquin are of the same age as the presumed Lower Miocene of the Kern region, or whether there is a discrepancy between the age determinations based on the one hand on mammalian fossils judged by comparison with the Great Plains faunas, and on the other hand on marine forms compared with those of the Atlantic coast.

By John C. Merriam and Robert W. Pack. Abstract. *Bulletin of the Geological Society of America*, vol. 24, no. 1, p. 128, March 1913.

CORRELATION BETWEEN THE TERTIARY OF THE GREAT BASIN AND THAT OF THE MARGINAL MARINE PROVINCE IN CALIFORNIA

In December, 1913, a party of students from the University of California working under the leadership of Dr. Bruce Clark, instructor in paleontology, obtained an interesting collection of remains of land mammals in Tertiary deposits north of Coalinga, on the west side of the Great Valley of California. As the Tertiary section in the Coalinga region is a part of the marginal marine series of Californian formations, and the mammalian remains obtained in these beds represent a land fauna best known in the epicontinental deposits ranging from the Great Basin east to the Great Plains region, this occurrence offers an unusual opportunity for correlation between the marginal marine province and the mammal-bearing deposits of the interior of the continent.

Evidence bearing on the problem of correlation between the Great Basin and the Pacific Coast province is particularly welcome at this time, since there has been reason to believe that the geologic scales used in the two regions have not coincided in the limits of the periods.

The mammalian remains obtained in the North Coalinga region were found at not less than four horizons, ranging from beds generally considered to be Lower Miocene or Upper Oligocene to a horizon of Pleistocene or Pliocene stage. The occurrence of the faunal zones in the sequence of deposits in the North Coalinga region is shown in the table.

The lowest horizon is characterized by abundance of horse teeth representing the genus *Merychippus*, and may be known as the Merychippus zone. At the second horizon from the base comparatively few remains are known. The presence of teeth of *Neohipparion* suggests the tentative designation of this portion of the section as the Neohipparion zone. The third of the principal horizons is characterized by the presence of a new species of horse

Science, n. s., vol. 40, no. 1035, pp. 643–645, October 30, 1914.

designated as *Protohippus coalingensis* and may be known as the Protohippus coalingensis zone. The latest fauna is distinguished by the presence of a large specialized horse, probably representing the genus *Equus*, and by remains of a form near *Cervus*. This may be known as the Equus-Cervus fauna.

Occurrence of Mammal Zones in Tertiary Beds of the North Coalinga Region of California

Time Divisions		Local Formations	Mammal Zones
Pleistocene		Terrace deposits	? Equus-Cervus fauna in part
Pliocene		Tulare	
		Etchegoin	Protohippus coalingensis
		Jacalitos	Neohipparion
Miocene	Upper	"Santa Margarita"	
	Middle	"Temblor"	Merychippus
	Lower		

The fauna of the Merychippus zone occurring in the "Temblor" beds, commonly recognized as Lower Miocene, includes the following types.

Merychippus, n. sp.
Tetrabelodon ?, sp.
Procamelus ?, sp.
Prosthennops ?, sp.
Desmostylus, near *hesperus* Marsh.
Isurus, sp.

The horses of the Merychippus zone correspond very closely in most respects to *Merychippus isonesus* of the Mascall Middle Miocene of the eastern Oregon region. The stage of evolution of the teeth of this form is not reached by any species of the Lower Miocene in America. The proboscidean, *Tetrabelodon?*, has no certainly known relatives in America earlier than the Middle Miocene of our accepted scale. The camel resembles a late Miocene type. It seems impossible to refer this fauna to a stage older than that of the Mascall Miocene of the mammalian sequence of the Great Basin province.

From the occurrence of the Merychippus fauna in the "Temblor" beds of the North Coalinga region, it seems clear that these marine beds, commonly referred to Lower Miocene or late Oligocene, are not older than mammal-bearing beds of the interior of the continent referred to Middle Miocene.

The "Temblor" beds of southern California represent a phase of the Monterey series of California, which is one of the best known and most widely spread of the divisions of the Tertiary. There seems good reason to believe that the Monterey series of California is approximately to be correlated with the Mascall Middle Miocene of the Great Basin.

A broad consideration of the lack of adjustment between the time scale of the Pacific Coast province and that of the Great Basin suggests that correlations of marine faunas of the Pacific Coast region, particularly those based on the percentage method, have tended to locate the time divisions relatively too far from the present or Recent. In late years, the refinement of specific characterization has proceeded very rapidly. Splitting the species has resulted in giving us a larger number of forms each of which has a relatively restricted geographic and geologic range. The percentage method, as proposed by Lyell, when used with modern species naturally results in pushing time divisions farther apart.

The lack of adjustment in the time scale also suggests the desirability of testing the relation of Middle Miocene mammal-bearing beds of North America to the formations of Lower Miocene age in the European scale.

The fauna of the second mammal zone of the Coalinga region comes from beds referred for the present to the Jacalitos formation. It includes a form referred to *Protohippus* by Arnold and Anderson, and a *Neohipparion* species of somewhat advanced stage. The *Neohipparion* material from this zone is insufficient for thoroughly satisfactory comparison. It seems in part to be related to a *Neohipparion* from the Rattlesnake Pliocene of the John Day region of eastern Oregon. This species does not appear to be very closely related to the well-known *Hipparion* species in the Ricardo fauna from the Mohave Desert.

The fauna of the third or Protohippus coalingensis zone of the

Etchegoin formation in the Coalinga region has as its most characteristic form a new species, *Protohippus coalingensis*,[1] which differs from all the described species found west of the Wasatch Range. It is most nearly related to a species represented in the Ricardo fauna of the Mohave Desert. It does not, however, seem to be identical with the Ricardo form. The stage of this fauna, in very general terms, seems to be Pliocene. Both the Etchegoin of this zone and the Jacalitos below it were referred by Arnold and Anderson[2] to the Upper Miocene.

The fourth fauna of the North Coalinga region includes a number of species of relatively modern aspect. These include forms referable to *Equus* and to *Cervus* or *Odocoileus*. This assemblage may be known for the present as the Equus-Cervus fauna. Its stratigraphic position is not entirely clear. The fauna is in part much like that of the Pleistocene.

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[1] *Protohippus coalingensis*, n. sp. Type specimen, No. 21341, Univ. Cal. Col. Vert. Palæ. Distinguished by large size, unusual narrowness of cheek-teeth in transverse diameter, small protocone and narrow, simple fossettes.

[2] Arnold, R., and Anderson, R., U. S. Geol. Surv. Bull. No. 398, p. 78, 1910.

AGE OF STRATA REFERRED TO THE ELLENSBURG FORMATION IN THE WHITE BLUFFS OF THE COLUMBIA RIVER

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INTRODUCTION

As a part of a programme of correlation studies on the Tertiary in the northern part of the Great Basin, the writers visited important localities of the Ellensburg formation of south-central Washington in June, 1916, in the hope of adding to the scanty representation of vertebrate remains known from these beds. A small collection was secured in the type area of the Ellensburg formation near North Yakima. A somewhat larger quantity of fragmentary material was collected in the great section of sediments appearing in the White Bluffs of the Columbia River in the vicinity of Hanford and Ringold, generally recognized as one of the largest of the typical Ellensburg exposures.

In the typical Ellensburg area near North Yakima remains of an equid or horse type were found representing the genus *Hipparion*, a group especially well represented in the earlier Pleistocene of western North America. From the White Bluffs localities the only determinable specimens representing the horse family belong to an advanced or specialized species of the genus *Equus*. In the widely

By John C. Merriam and John P. Buwalda. *University of California Publications, Bulletin of the Department of Geology*, vol. 10, no. 15, pp. 255–266, pl. 13, April 14, 1917.

known North American occurrences of *Equus* there is as yet no reported discovery of a species of such an advanced type in beds earlier than Pleistocene.

It is quite certain that the evolution stages of the horses represented by the Ellensburg and White Bluffs specimens belong to widely different periods, of which the White Bluffs stage is the later. The Ellensburg formation is evidently Miocene to early Pliocene in age; the White Bluffs exposures represent a distinct and considerably later stage in the history of sedimentation in the eastern Washington region.

It is the purpose of the following paper to give a brief statement concerning the physiographic and geologic features and the fauna of the White Bluffs exposures, which are here described as the Ringold formation.

Owing to brevity of the time spent in the Ringold area by the writers, data concerning structure of the formation, extent of the area occupied, and stratigraphic relations to the Ellensburg formation must be considered incomplete.

Previous Knowledge

The White Bluffs section was considered by I. C. Russell[1] "the most typical section of the John Day beds to be seen in Washington." As the name John Day was used by Russell with reference to the formation now known as the Ellensburg, it is to be presumed that he considered the White Bluffs approximately contemporaneous with the Ellensburg. The exposures were stated by Russell to range up to 500 feet in height, and to be composed of approximately horizontal or only slightly tilted strata. The beds were reported to consist of fine sands, clays, and strata of volcanic ash. A section taken at the southern end of the cliffs measured 496 feet in thickness.

Russell[2] reported that fossil bones of large animals had been found in the White Bluffs beds, but that their significance was not known. The exposures were considered favorable ground for collecting vertebrate remains. Reference was made to deposits presumed to be Pleistocene in the region occupied by the White Bluffs sediments, and the possibility noted of confusing Pleistocene

[1] U. S. Geol. Surv. Bul. no. 108, p. 97, 1893.

[2] Ibid., p. 98.

and White Bluffs beds. Russell mentioned a locality at the southern end of the White Bluffs exposures, about fifteen miles above Pasco, where a number of large fossil bones, assumed to have been derived from the White Bluffs beds, were found in a river terrace banked against a cliff formed of horizontal White Bluffs strata. He stated that no molluscan shells were found in the sediments, and suggested the possibility that immense quantities of volcanic dust falling into the water may have made it unfavorable for animal life.

In 1903 George Otis Smith[3] referred to the White Bluffs exposures described by Russell, and called attention to evidence indicating that while in the Yakima region the Ellensburg formation is of fluviatile origin, farther east along the Columbia the formation is of lacustrine character.

Calkins[4] discussed the White Bluffs in 1905, and gave from the upper end of the cliffs a section 225 feet in thickness, consisting of sands and clays with some ashy material. Other writers were followed in correlating the White Bluffs exposures with the Ellensburg, but Calkins noted that "the general character of this section offers some points of contrast with the typical section measured in the Ellensburg Quadrangle." The materials included in the White Bluffs exposures were shown to be fine and less commonly cross-bedded than in the typical Ellensburg, and tuffaceous material was stated to be less abundant. The suggestion was made that a part of the White Bluffs beds may be of lacustrine origin, but that certain of the sandy layers were probably laid down in rivers. Calkins found no fossils in the White Bluffs exposures, but noted the reported occurrence of shells and bones in the bluffs near Pasco.

FAUNAS

In examining the White Bluffs in June, 1916, the authors collected mammalian material from exposures about midway between the base and the summit of the bluffs on the east side of the Columbia three to four miles below Hanford (loc. 3031). Later in the summer a small collection was secured one or two miles north of Ringold School (loc. 2757) a few miles south of the first locality.

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[3] U. S. Geol. Surv. Professional Paper no. 19, p. 18, 1903.

[4] Calkins, F. C., U. S. Geol. Surv. Water Supply and Irrigation Paper no. 118, p. 35, 1905.

The collection from the locality near Hanford (loc. 3031) includes the following forms:

Megalonyx, small species, probably new
Equus or Pliohippus, calcaneum
Camelid, small, near Pliauchenia
Camelid, possibly larger than first mentioned form
Cervid, antler fragments
Leporid, new genus
Fish vertebrae and other elements of skeleton
Testudo, fragments

With the exception of the ground-sloth remains the material from locality near Hanford (loc. 3031) is not well preserved, and this form furnishes the only type diagnostic of any recognized faunal stage.

The *Megalonyx* specimen consists of a well-preserved maxillary with all four cheek-teeth in perfect condition. The species resembles the Pleistocene *M. wheatleyi* in size, but is probably new.

A single specimen representing the horse group consists of a considerably worn calcaneum or heel bone somewhat smaller than the average of calcanea of the Pleistocene horses, and exceeding little if any the average of *Pliohippus* from the West Coast Pliocene. It is considerably larger than the specimens commonly found in the West Coast Miocene.

Of the camel remains none of the fragments can be generically determined with certainty. A portion of a tooth and an incomplete proximal toe bone seem to represent a type not more advanced than those of the later Tertiary. They appear smaller and less specialized than the known forms of the West Coast Pleistocene.

Deer are represented by fragments of antlers, some of which show the burr well preserved. The deer of the Pleistocene and later Tertiary are not as yet well enough known to furnish a good basis for comparison of the fragments represented in the White Bluffs collection.

A single upper cheek-tooth of a rabbit-like form obtained in the White Bluffs beds is considered by Dr. Lee R. Dice to resemble in its tooth-pattern a new genus known from the middle Miocene and early Pliocene of northern Nevada. In this specimen the enamel folds on the re-entrant angle are comparatively coarse, in contrast to the finer folds seen in the teeth of the later rabbits.

The fish and tortoise remains have not shown characters furnishing definite evidence concerning geologic position.

The material obtained one to two miles north of Ringold School (loc. 2757) includes upper and lower cheek-teeth and fragments of the skeleton of a horse in which all the characters noted are those of an advanced member of the genus *Equus*.

In the upper cheek-teeth the protocone is long anteroposteriorly, the anterior lobe projects far in advance of the isthmus connecting it with the protoconid, and the inner wall is markedly concave. The fossettes are narrow, and the borders show fairly complicated folds. In the lower cheek-teeth the inner faces of the protoconid and hypoconid are flat. The metaconid-metastylid column is long anteroposteriorly and broadly grooved internally. The valleys anterior and posterior to the metaconid-metastylid column are narrow transversely, as in *Equus*. The parastylid is short. A single splint bone representing digit four of the posterior foot is very short, and though the tip is absent the splint narrows so rapidly below that phalangeal elements must have been absent.

It is difficult to make certain of the specific identity of isolated *Equus* teeth, but the specimens from near Ringold School are at least as advanced as those of *Equus occidentalis* from the Pleistocene of Rancho La Brea, and may be even more specialized.

The assemblage of forms from the White Bluffs near Hanford taken as a whole seems more advanced than any fauna known heretofore in the Miocene of the Pacific Coast and Great Basin provinces. Megalonychid sloths are reported from the Pliocene, but are imperfectly known and of doubtful systematic position. Deer such as are represented in the collection are not known in Miocene beds of the Great Basin province. The earliest reported occurrence of typical deer in the region west of the Wasatch is in the latest Etchegoin Pliocene of the Coalinga region. The fragmentary camel remains might represent late Tertiary. They seem of earlier type than any known to the writers from the West-American Pleistocene. The fragmentary equid specimen might be from a late Tertiary or from a Pleistocene form.

The collection from near Ringold School taken by itself would be considered to represent Pleistocene.

The question of relative age of the material from the two White Bluffs localities naturally presents itself. There is some suggestion of difference in preservation between the two collections. The fossil specimens from near Ringold School show somewhat less evidence of corrosion and decay. In order to determine whether one collection might have been derived from the strata in the White Bluffs and the other from terrace deposits laid down against them, as reported by Russell[5] in the case of certain other deposits containing fossils at the southern end of the bluffs, both localities were carefully investigated. It was found that at both stations the bones were derived from layers of sand and gravel in the steep faces of the White Bluffs, a little below the middle of the exposed section, and that the strata yielding the fossils are part of the White Bluffs section and not terrace deposits. The locality one to two miles north of Ringold School is shown near the right-hand end of figure 1 in plate 13.

There is every reason for considering that the collections secured near Hanford (loc. 3031) and near Ringold School (loc. 2757) represent approximately the same horizon in the White Bluffs sediments. The best preserved specimens from both localities seem to furnish definite evidence of very late Cenozoic age. The ground-sloth jaw from the Hanford locality and the *Equus* teeth from the Ringold School locality both represent types generally considered characteristic of the Pleistocene.

As the separation between the Pliocene and Pleistocene is not yet clearly determined on a faunal basis in the Great Basin region, one might admit for the present the possibility of including in the latest Pliocene the faunal stage represented in the White Bluffs exposures. Not even the latest faunas referred to the Pliocene up to the present time include horses of a stage as advanced as that of the Ringold School fauna, and the evidence on the whole favors Pleistocene rather than the latest Pliocene.

Geology

Stratigraphic Section.—From a point twelve miles above the town of Pasco, in south-central Washington, bluffs several hundred feet in height extend about thirty miles northwestward along the eastern bank of the Columbia River. Because of their light color these magnificent exposures have commonly been known as the White Bluffs.

The strata in the White Bluffs clearly represent a formation distinct from the Ellensburg, as is indicated by the difference in age expressed in their faunas, and by the physical evidence. The writers propose the name Ringold formation for these beds, from Ringold Post Office, situated at the base of the bluffs. The known thickness of these strata exposed by the downcutting of the Columbia River is approximately 500 feet; as the river has not reached the base of the section, the total thickness is not known. The Ringold formation consists, as noted by earlier writers, chiefly of light-colored muddy sandstones and sandy clays, and in minor part of fine gravels, volcanic ash and calcareous strata.

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[5] Russell, I. C., U. S. Geol. Surv. Bul. no. 108, p. 99, 1893.

The following is an estimated section of the Ringold formation in the White Bluffs three to four miles below Hanford:

	Feet
7. Loose yellowish clayey sand (summit of section)	85
6. Gray limestone, often brecciated, irregular in thickness, forming a resistant layer	3
5. Cream-colored clayey sandstone, lacking resistance to weathering	75
4. Brownish-yellow clayey sandstone, distinctly but thickly bedded, more resistant, standing out as bluffs	75
3. Yellow sandy clay, unindurated, poorly stratified	25
2. Cream-colored clay, thinly bedded, including occasional thin layers of sandy material, giving quite prominent outcrops	25
1. Nearly white clayey sandstone, in places pure sand, with occasional thin gravel layers of polished quartz pebbles. Fossils occurring near top of this member, which extends from the Columbia River up to an elevation of about 175 feet above the river	175
Approximate thickness of section exposed above Columbia River	503

Viewed from a distance individual beds may appear quite persistent in the face of the bluffs, but the bulk of the material is not thoroughly classified as to size, and therefore not sharply stratified. The coarser materials are waterworn. Occasionally beds of coarse angular materials, chiefly basaltic in character, are found at the top of the bluffs, but these are evidently later deposits laid down in channels cut in the Ringold by water courses heading in the country to the east and north. The strata of the Ringold lack induration and are notably softer than most exposures of the Ellensburg. While they exhibit steep slopes, especially where the Columbia has recently cut into the base of the bluffs, exposures tend to assume rounded outlines and a subdued topography, even under the prevalent conditions of semi-aridity.

Physiography and Structure.—Direct observations on the structure of the Ringold were limited to the White Bluffs exposures, but certain inferences as to the attitude of these beds in other parts of the area seem possible from physiographic considerations. So far as could be judged, the strata in the White Bluffs lie parallel to the water surface of the Columbia River. All recognized cases of apparent deformation seem to be due to landslide.

The White Bluffs follow the river closely from a point ten or twelve miles north of Pasco to the northwestward for about thirty miles. The bluffs end at a point across the river and a short distance below the town of White Bluffs. Where the beds are not locally reduced by erosion, the crest line of the bluffs is remarkably even (pl. 13, fig. 2). Without having determined its elevation above the river at many points, the crest appears to maintain its height of about five hundred feet above the stream throughout the whole thirty miles.

Between the northwestern end of the White Bluffs and Priest Rapids, a distance of fifteen to eighteen miles upstream, no high bluffs occur, but low light-colored exposures appear some distance from the river. The dissected character of this area indicates that it has suffered marked degradation in contrast to the relatively undissected areas lying to the east of the Columbia in the Ringold region. The more marked dissection has probably resulted from the greater drainage derived from the Saddle Mountains to the north.

The White Bluffs, extending along the east side of the Columbia River, have no counterpart in similar features on the opposite side of the stream. To the west of Hanford is an area with a rolling topography, on which occur occasional outcrops of soft beds similar to those in the White Bluffs. This area extends westward to the base of the Yakima Range and has a maximum width of perhaps sixteen miles. Practically all of it lies at less elevation above the Columbia than the top of the White Bluffs. It is believed that the Ringold once extended over this region of low hills between Hanford and the base of the Yakima Range, and that it was largely cut away by the Columbia before it had shifted eastward to its present position, and while its channel lay at a higher level. It has been this gradual shifting eastward, continued to the present time, which has produced the White Bluffs on the east side of the Columbia, in contrast to the degraded character of the area on the west side. The cause of the shifting cannot be stated with certainty, but it is probably due in part to deflection of the stream by the north side of the Yakima Range.

The surface extending several miles to the eastward from the summit of the White Bluffs is remarkably even, excepting where interrupted by occasional drainage courses which have cut below its level. The marked evenness and approximate horizontality of this surface as viewed from the summit of the bluffs, and the apparent absence of residual hills upon it, suggest immediately that it is a surface of aggradation rather than one of erosion or of river planation. Its striking parallelism, so far as the unaided eye may judge, with the strata of the Ringold in the face of the White Bluffs, strengthens this idea. Unfortunately extensive observations have not been made on the structure of the Ringold over more than a small portion of the area in which it is exposed, so that it cannot be stated with certainty that upturning and bevelling have not occurred in some of its marginal areas.

Mode of Deposition.—The available data indicate that the Ringold formation was deposited in a basin the walls of which were essentially the Yakima Range on the west, the Saddle Mountains on the north, and the lava plateaus on the east and south. It is probable that the flat area extending east from the White Bluffs and lying about five hundred feet above the Columbia is to be regarded as an undissected remnant of the aggradational surface developed at the close of the period of deposition, and indicates the elevation to which the basin was filled.

The Columbia cuts through high ranges like the Saddle Mountains instead of flowing around them, and is an antecedent stream in this part of its course; in pre-Ringold time its channel therefore lay across the area now occupied by these sediments. The presence of the Columbia in this region at the time the sediments were laid down, and the similarity of the sediments to those transported by the stream at the present day, make it probable that the Columbia deposited this formation. Whether the strata were laid down in a lake formed in the course of the stream, or as flood-plain deposits, is not certain, as the limited time spent in the area did not permit an examination of the peripheral areas to determine the presence or absence of such evidence as beaches, bars, and other lacustral features. The muddiness of the Ringold sandstones and the sandiness of the clays are, however, to be contrasted with the cleaner strata usually produced by the efficient classifying agencies of lacustral waters. The apparent scarcity or absence of freshwater molluscan remains, usually quite common in lacustral beds, and the presence at different localities of scattered bones of land mammals, also favor the belief that the deposits are largely of flood-plain origin.

Area.—Without having mapped its boundaries, the Ringold formation appears to the writers to occupy an area of at least 300 square miles, and may extend over 500 or 600 square miles. To the north the beds apparently reach to the lower slopes of the Saddle Mountains. Their eastward limit is not known, but it is certainly several miles to the east of the Columbia. Their southern boundary likewise has not been traced. As the Ringold deposits rise about 500 feet above the Columbia at the southern end of the White Bluffs, and the river has excavated a valley several miles wide south of this point, it is probable that the beds originally extended a considerable distance down the river, perhaps beyond Pasco. To the west the beds appear to be bounded by the base of the basaltic Yakima Range, which lies at distances from the river ranging up to fifteen miles or more. Considering the height to which the Ringold rises above the river in the White Bluffs region, it is probable that this formation originally extended up through the gap which the Columbia has cut across the Saddle Mountains, and that it was deposited over areas north of that range.

More precise data concerning the areal distribution of the Ringold and regarding its physiographic relations will be necessary before it will be possible to offer a satisfactory statement of the factors which caused the Columbia to deposit these sediments. From general considerations it is probable that the accumulation was due: (*a*) to an uplift across the course of the Columbia at some point downstream, or (*b*) to a subsidence of the region which the Ringold now occupies, or (*c*) to a change in the relation of the detrital load of the Columbia to its transporting power. The last condition might be associated with climatic fluctuations of the Glacial period or with marked changes in position of the course of the Columbia which are known to have occurred in the hundred miles or more of its channel north of the Saddle Mountains. Additional field-work, which the writers hope to carry out during a coming season, will be required before this problem can be solved.

Relation to the Ellensburg Formation.—In view of the difference in age between the Ellensburg and Ringold faunas it is important to know the stratigraphic relations of the formations in which they occur. It is probable that the two sets of beds come in contact on the western border of the Ringold, and perhaps at other points, but none of these localities have been examined. If the very even surface extending eastward from the White Bluffs be correctly interpreted as a remnant of the original surface of deposition, the Ringold strata probably lie approximately flat along the flanks of ridges consisting in part of folded Ellensburg strata. Such field data as have been obtained, taken with the palaeontologic evidence indicating difference in age, suggest unconformity between the two formations.

Transmitted March 7, 1917

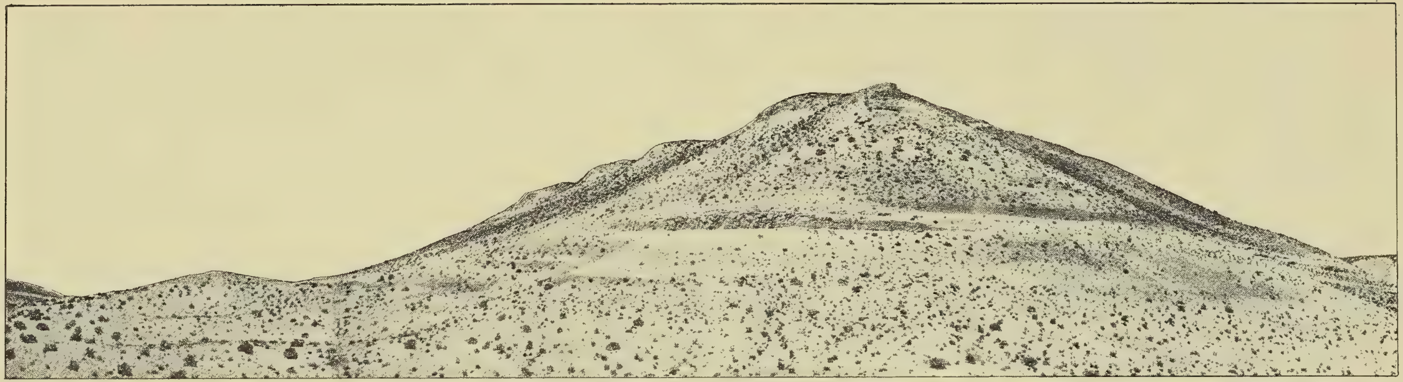

FIG. 1. Exposures of Ringold formation in White Bluffs (loc. 2757), one to two miles north of Ringold, Washington. Horse teeth and bones were secured at point near right end of figure at horizon just above resistant layer shown half way up bluff. Looking north.

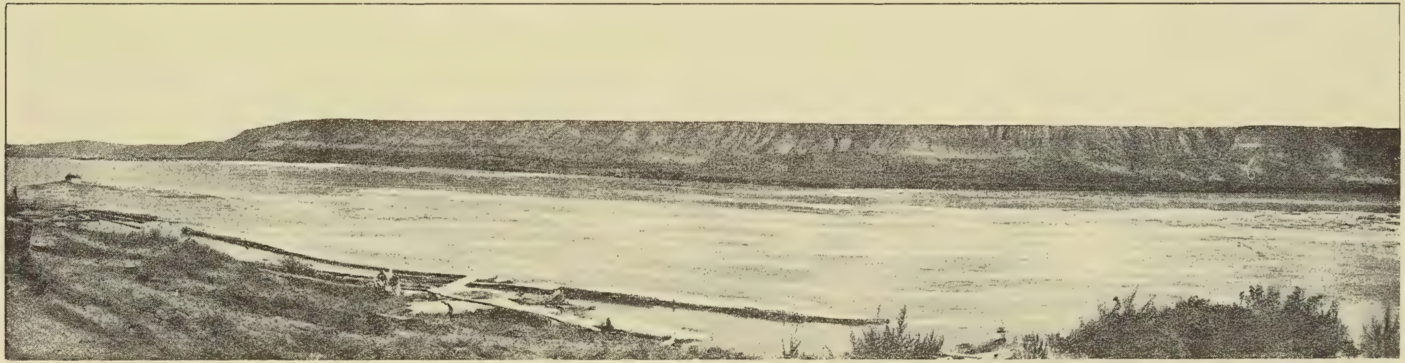

FIG. 2. White Bluffs across the Columbia River from Hanford, Washington. Note evenness of skyline and parallelism of Ringold strata with crest of bluffs and with water surface. Height of bluffs approximately five hundred feet.

EARTH SCIENCES AS THE BACKGROUND OF HISTORY

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INTRODUCTION

THE present day of great concepts is witnessing expansion of our vision so as to include in each personal relation the wider contacts of community, state, and race. We attempt with shifting viewpoint to visualize the complicated political, economic, and psychologic factors determining attraction and repulsion of the major human groups. Most of us now consider national politics in terms of their international significance, and see great problems of the people projected against the background of interlocking world relations. It is clear that this enlarged vision must for the future be the normal view. Unless by some political cataclysm civilization breaks down completely, we shall retain our close connection with other nations, and cannot return to the kind of isolation possible in the age before space was narrowed by electricity and steam, and extensive international trade pointed the way to more efficient use of the world's resources.

With the widening of our mental vision, space relation is not the only element to change. We see needed readjustment of national boundaries and regrouping of peoples brought about by reason of conditions antecedent to present time by long or short periods. More clearly than ever before is it necessary for us to view world affairs, and in them our own connections, by the perspective of space plus time. It may be that by reason of selfish political and

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economic motives we find here and there expression of judgment giving evidence of geographical and historical blindness, but such is not now the normal sight of the average man.

We have, moreover, come to see that history, or depth of view, is not merely a continuity with which we must reckon, but that there appears in it the evidence of calculable movement, subject to law, and reaching forward to express itself in the trend of present and future affairs.

Concept of History

The concept of history as generally accepted has undergone extraordinary changes in recent years. History as read and taught has expressed only in part the broader relations of events with the view to indicating their true bearing on the present. In its origin as a constructive science much of history was concerned with the emotional side of national propaganda. In varying measure, in our own and in other countries, it has been the instrument of propagandists, aiming to promote a nationalistic spirit which makes for the strength of one group without regard to right relations outside. Fortunately, we *do* find here and there interpretations which have clearly stated the continuity of events, their real relations and significance in the world sense, and their proper trend.

Not less insufficient than the use to which history has been put is in many instances the structure of the account presented. Continuity has not always been the fundamental factor. Descriptions of events in series, but unrelated, have often formed the basis for discussion, and fundamental laws or scientific principles have not always played an important part.

Reaction against the incomplete view of historical study is in some measure due to application in human affairs of the hypothesis of evolution or development growing out of the fundamental historical sequence of geology as presented by Lyell and applied in the broad biological concept of Darwin. Assuming that man remains on a constant level, representing the type as created, human history might show indefinite fluctuations of movement; or it might be cyclic, each cycle representing approximately the same plane of development. According to the evolution hypothesis, the trend of the living world would be toward the more specialized, or more complicated, or more advanced. Although it might be cyclic, each cycle would represent a higher stage, and the path would be spiral. According to the developmental or evolutional interpretation, every part of a historic sequence is related to every other part, and each feature of past series contributes somewhat to the interpretation of the present. This concept gives us for every portion of historic succession a formula, through which, with a certain degree of accuracy, the line may be projected beyond the present. Viewed in this light, history becomes not merely a teacher by comparison or by analogy, but interprets the development of present conditions, and also furnishes a key to the future.

Rarely has the range of historical account included all influences actually involved. Largely by reason of the fact that the world is so complicated, there is no connected statement which shows the happenings as a whole with their interlocking connections. All records are merely pieces, or pieces of pieces, limited to one phase of the subject, limited to one portion of the world, and limited to a small space of time without relation to what precedes or follows. True world history scarcely exists.

Analysis of the elements composing the fabric of history, considered in its enormous complication and as a world problem, shows that there can be no question regarding the need for every element of knowledge which may be brought to bear, for interpretation of our present situation and requirements, and for guidance of mankind in decisions on those greater problems demanding for their proper settlement a foresight reaching over periods including more than a single generation. We need light with increasing brilliance and in many dark corners.

Present world questions will be solved in part by men who trade and men who study those who trade, in part by those who do politics and those who rule, and those who study rulers and politicians. But the only view that can show us where we are and whither we ride is one that, with other items, includes at least the outlines of the path over which we have come.

Purpose of Paper

The point of my story in this paper is that the farther back we see the path clearly, and the better we know our progress over it, the more certain we are to eliminate the minor curves and determine the true direction and the rate of speed to expect.

I am suggesting that the deepest view of history is desirable for purposes of most fundamental decisions; that, no matter how far back this vision leads us, if it continues to add to knowledge of what we are by showing us how we came to be, it is desirable and should be secured.

Contribution of the Sciences to History

The sciences especially concerned with historic sequence are astronomy, geology, geography, paleontology, biology, and anthropology. Astronomy, with its broad conceptions of stellar evolution, concerns us because it discusses the origin and early history of our planet. Geology and geography deal directly with the earth. Paleontology, representing biological history, must go to geology for its record. Anthropology has, as one of its most important phases, the history and origin of man.

The field of the astronomer, with its myriad bodies of the heavens, presumably represents wide range in stage of development of the stellar systems within our view. Yet, with all our information as to the stages through which these bodies may proceed in their evolution, there is but little positive evidence on which we may depend. We may note modifications in the surface of the sun or in the clouds of Jupiter, or we may observe the varying brightness of the stars, but there is little in these variations which we can consider as more than incidental fluctuation. Our knowledge of evolution of the stellar universe must depend largely upon comparisons of stars of various types, or of groups of stars and nebulæ which we assume to represent incipient stellar systems. The nebular hypothesis, which has served as the type of evolution of the solar system and as a basis for an interpretation of the origin of the earth, is called in question to such an extent as to be no longer acceptable to a large group of astronomers. The planetesimal hypothesis, developing similar world systems out of spiral nebulæ, seems also to suffer under recent criticism. For practical comparisons in study of world evolution, we appear to have one of the most important sources of information in the history of our own planet. For the universe in the large we can prove little more than that there is shown a process of development for which infinite time is required and in which definite cycles are determined.

Our greatest scientific contributions to study of history and of origins have come through geological and biological investigations. Geology is the greatest of all historical sciences. From comparative and experimental studies alone biology makes large contribution, but its distinctly historical phase lies in the field of paleontology, in which the life record is read from the geological book. To geology and biology, furnishing together the life records, anthropological history must be added, reaching back, as it does, into geological history and expressing the beginnings of our account of human life and activity in terms of geology and paleontology.

For the purposes of this paper, geological history may be divided roughly into two portions, one represented in the known section of stratified rocks formed through the piling up of sediments and by the outwelling of molten material spread on the surface or squeezed into the strata. An earlier period expresses in a more doubtful manner the partly astronomic history of the earth antecedent to the record presented by the lowest or earliest known strata.

The astronomic period of our earth's history is a subject for investigation by astronomer, physicist, and geologist. As yet the results of studies in this region are in large part of a speculative nature. The field furnishes one of the most attractive opportunities in science for further investigation. Although this phase of the problem has in it very much of fascination, the contributions are as yet of such a nature as to contribute little toward the objects of the present discussion. I shall therefore refer to geologic history only in terms of the distinct record extending to the lowest known strata in the second chapter of the account.

The length of the period which remains after elimination of the earlier, or astronomic, period may be very short, measured against the total age of the earth. We know that the lowest strata, wherever we find them, rest upon rocks which have been molten and in their molten state have destroyed the basement upon which the oldest known stratified rocks now rest. We admit, therefore, that not only have we lost the record before the earliest strata were formed, but that the earliest strata themselves have disappeared. The record remaining is, however, by no means brief in terms of human understanding. Few recent estimates have suggested that the section comprises less than two hundred thousand feet of strata, or that the time involved measures less than one hundred million years. This time may not be long compared to the entire age of the earth, and may not be more than a moment compared with the age of our solar system, but it furnishes all that we require for purposes of interpretation of human history.

Reduced to their simple terms, the geological data of the stratified record give us a history of the accumulation of sediments, of movements of the earth's crust, of the making of continents and ocean basins, of volcanic activities, and of climatic changes. In this evidence is included a history of the forming of mountains, and the wearing down of mountains and continents by the processes of erosion to form the sediments spread over great basins of accumulation.

This history presents, as its first significant lesson, the fact of the instability of the earth's crust and the evidence that throughout geologic time, as we know it, the surface has shown diversity of form dependent upon vertical movements of large magnitude. By offering the opportunity for erosion forces to act, the movements which have produced continents and mountain ranges have also been responsible for accumulation of the sediments washed into the deeps to form the strata from which our record is read. Also intimately related to the succession of crustal movements is the history of igneous activity evidenced from time to time in the great extrusions of molten material forming successions of lava flows intercalated in the sedimentary series. The history of climate furnished us through a great variety of data gives evidence of almost continuously fluctuating conditions in the physics of the atmosphere ranging between high and low humidity, and between temperatures comparable to those of the glacial periods and the climate of tropical or subtropical regions of the present day. The salient features of climatic history are the continuous change and the evidence of comparatively slight range of temperature for the earth as a whole within the span of geologic time as known.

Earth history, as we see it, shows from the most remote periods to the present constantly varying surface conditions dependent upon an unstable crust; continents and mountains arise only to be subject to the steady grind of erosion, wearing them away and spreading the debris over the seas. Always do we find land areas and seas, but with much variation as to size and form; always with temperature near that of the present, though fluctuating from warmer and more humid to climates like that of the Glacial Period.

Within the whole span of geological history and its continuous changes recorded, the phases of purely physical history presented do not show us in any of their various aspects definite progression or trend which may be described as an evolutionary process. It was once our practice as geologists to place emphasis on the geological history of the earth as the continuation of a graded or evolution series based on the succession of stages described in the nebular hypothesis. According to this view, we seemed to see in climatic evolution a gradual movement away from the conditions of the primitive heated earth and toward the present temperature of a cooling sphere. We once thought we saw the early atmosphere fit only for lower organisms and later cleared and purified for the higher types of life. With better understanding of climatic history, it comes out more and more distinctly that while the earth's climate fluctuated continuously, there is no clear evidence of definite progression through a series of stages dependent on gradual cooling of a once highly heated globe.

So in other phases of purely physical history we have worked out what seemed at first to be evolution series, which have all proved finally to be nothing more than cycles that may be represented by somewhat variable formulæ. As nearly as we can determine, the physical history of the earth within the span of time represented by our legible record has been so nearly stabilized as to show little or no variation which may not be considered merely as fluctuation.

As evidencing a continuously changing evolution series, the most extraordinary record of all history is that included in the paleontologic record of life, running down through the whole story of geology, practically to the earliest strata.

Not only do we find the character of the earlier stratified rocks indicating atmospheric and climatic conditions similar to those now obtaining on the earth, but we find these rocks containing traces of living forms such as now are fitted to these climatic conditions. Through the whole stretch of the strictly geologic record, conditions in temperature and humidity evidently kept within the range permitting development of living forms. The period in which life came to be on this earth is represented by a chapter now destroyed.

The life record is, to be sure, fragmentary, but in many groups it is extraordinarily full. Although there is much to be desired, out of the long series of events, certain features in the evolutionary sequence are so clear as to be unavoidable. We find this record showing: (1) that life has been in almost continuous stage of change. From top to bottom of the geologic section, in no two great groups of strata do we find that the assemblage of living forms represented are the same; (2) we know the life of each stage to exhibit closer resemblance to that found in strata immediately above and to that immediately below than to the life representation of the more remote divisions, and (3) we note that the series of forms with certain common characters, but differing in grade of specialization, generally tend toward greater specialization from earlier toward later time. The way in which the changes took place may not always be evident, and the paleontologist may admit his ignorance of the cause, but the fact of more or less rapidly changing definitely specializing series of presumably connected or related types seems reasonably clear. The evidence, taken in its entirety, furnishes strong support for the view that life of all these stages is related, that the life of each stage is derived or modified from that of a preceding stage, and that the whole series indicates the continuity of life from earliest to latest time.

Unlike the sequence in purely geologic history, we have here continuity and continuous progress in a definite direction. We have, however, noted that there is probably close relation between the continuous fluctuations of the progressing living world and the fluctuations of earth climate and earth crust. Movements of the crust producing change of topography and variation in distribution of land and water, taken with changes of climate, must have had important influence in keeping the currents of life moving. A dead earth without crustal movement and with uniform climate might have limited greatly the possibility of biological evolution. The fluctuations in physical conditions on the earth in geologic time have, therefore, great significance in consideration of the larger problems of earth history.

It is not my purpose to bring into review, or to discuss, the tremendous field for evolutionary studies in the groups of animals and plants whose history we find represented in the rocks. One after another these have been considered by specialists in various fields. In all cases, the laws of which I have just spoken find expression, whether this be in the evolution of the nautilus, dinosaur, or elephant. Given lapse of time and change of environment, the old goes out and the new comes in, the unspecialized gives way to the specialized. As the ages go by, in each successive step, almost without exception, we find a higher level of life, representing greater intelligence, greater efficiency, and greater progress.

The most interesting of all the series of fossil forms represented in the geological record, and the most interesting in the first instance because the series begins well back in the geological record, is that succession giving us the beginnings of the race of man. The earliest known traces of human beings represent a normal part of the life of the earth in a period so remote from the present that our calculations must be in terms of eons rather than of millenniums. We find that since these first manlike forms appeared great crustal movements have changed the face of the earth, and that the climate has shifted back and forth many times through relatively wide ranges of temperature. We know also in this period a long procession of living generations of animals other than man passing through the ages and disappearing.

We find the first remains of humans more beast-like than any living race, approaching ape-like forms both in skeleton and skull, and meeting the requirements of the missing link. We find this first stage followed by others still different from man of the present day, but approaching more nearly to the modern type. The laws applicable to the evolution of other groups apply to man. We note the same relation of physical change in man to lapse of geologic time, to climatic and crustal change, and to other factors in the physical history of the earth. So far as the evidence goes, it meets the requirements of those who assume the emergence of man from the animal in the manner in which innumerable other organic types have arisen in the long life record as we know it.

Through still later stages of the geological and paleontological record man advanced in intelligence and culture, his environment gradually approximated present conditions in both physical and biological factors, and we record the history of these stages partly in terms of archeology, which in turn merges into history based on written records.

Through the evidence of archeology, paleontology, and geology we see human history extended back stage by stage until we go from history to prehistory, where in ages remote and in environments strange we find man already widely distributed over the earth, varying as to kind and culture and advancing as to ideas. With this view there seems no escape from recognizing that not merely the foundations of history, but the greater part of the human span, falls within a realm the approach to which has been largely by investigators concerned with the problems of earth science and using the methods developed for this field of study.

The present paper is addressed to the relation between this material, obtained from the earlier segment of history which has been briefly outlined, and that which comes within humanistic study based on modern man. You may, perhaps, urge as in Huxley's remark concerning the significance of information obtained through a "medium": that, whether or not we are truly dealing with "a message from beyond," there may not be in what we learn anything worth attention. It may be thought that remoteness means by definition diminution of value and interest, and that events of ancient history diminish in importance as the square of the distance, or at a more rapid rate. At present my only answer would be that what is first is commonly, if not always, fundamental, though fundamental characters may be overshadowed by superficial.

It is not my purpose to give detailed application of present and future use for the facts of history seen in the outlines of the longer span secured by study of earth sciences. I may, however, illustrate by one or two examples.

Of the many elements in the problem of world government which now confronts us, there seems to me every reason to believe that race as a fundamental factor is inferior to no other involved in consideration of unity in organization. Assuming that culture, speech, economic interest, and political organization may temporarily overshadow it, in the last analysis we may not avoid reckoning with this factor, not merely in consideration of the organization of the greater groups of human beings, but also in the relations of slightly separated types. The fact that we may refuse to consider it does not prevent its acting as a continuously operating element, which remains while prices go up and down, political parties come and go, and national units group themselves in this way or that.

Race is the product of evolution in a changing environment, the conditions of which have been determined by factors of geological significance. As a relatively simple illustration, the history of the original Americans is a tangled web in which there is inextricably woven the story of great continental and climatic changes and of vast intercontinental migrations of plants and animals. The history of European and Asiatic races is of like order. The relation between Africans and Caucasians or Africans and Mongolians is dependent on similar conditions reaching into remoter periods and still more difficult of interpretation.

The Balkans represent the fault-line of Europe, because this is a region of overlapping races and subraces, conditioned in their history by extraordinarily complicated migrations determined and directed in part by physical features and climatic changes. Although the Balkans present a problem of the greatest difficulty in the racial and political sense, they place before us a study simple of aspect and significance compared with the larger race questions which we have now to encounter in world government, the difficulties of which we shall not improbably see in larger measure as the centuries pass.

Shall we in attempting to solve these incalculably complicated questions look only at the present balance of trade, the dominance of particular political parties, the present grouping of social elements, or the present military strength of the nations involved; or shall we, realizing the vastness and the complexity of the difficulty, bring to the light every element concerned, scrutinizing with especial care those factors which seem to be fundamental and more clearly of permanent significance? Unless the larger or broader view is taken, I feel that we shall fall short of the interpretation of humanity needed, in order to fit the nations of the world together into one great unity in which each people supplements the needs of the others, and thus gives to every group, as well as to every individual, that freedom to develop its own peculiar talent and grow into that fullest usefulness which we assume to be the natural right of all.

The question of race just described is only one phase of the historical problem, in which the background represented by the field now occupied mainly by earth sciences becomes of real significance.

In passing I may only mention two other examples illustrating the relation of historical data from earth sciences to affairs of life of today. I believe I am correct in stating that earthquakes are by most persons considered as extraordinary happenings, without relation to the normal order of events with which we have acquaintance. The geologist, however, recognizes them as the natural corollary of crustal movements. Regarding continuance of such movements, he must believe that the only basis for considering that crustal activities have ceased is to assume some extraordinary intervention definitely holding back forces which if unfettered would result in further crustal disturbance and in earthquakes. Such disturbances have affected the earth since the beginning of our geological record. The geologist who views the history of crustal movement considers that there is no reason for believing that the crust is now stabilized, and that we may expect other movements and other earthquakes. We know fairly the physical laws that govern earthquakes. We can prepare to meet them in such a way as to eliminate most of the dangers incident to their action, but it will take the passing of another generation before we reach a stage in which the clear lessons of earth history bearing on interpretation of these phenomena will become the basis of common practice, such as dictates the precautions which have made it possible for us to build in the summer against the rains of autumn and the snows of winter. Many of us still build as if the last earthquake suddenly ended the series measuring back for tens of millions of years.

Still more difficult may it be for us to make use of the lessons of prehistoric history relating to our adjustment to biological environment. In America we live largely on plants and animals of Old World origin, not because the abundance of these types is so much greater than that of America, but because man has lived a longer time in the Old World, and within the period of his early history, reaching back to past geological periods, he has experimented intentionally or accidentally with Old World plants and animals for a longer time than has been given to contact with the native life of America. There are many who do not recognize this relation to the world of undomesticated organisms about us, and seem to feel that some plants and animals were predetermined to domestication, while others can never serve us.

Left to chance, as during past millenniums, we may in time develop a series of useful American plants and animals corresponding to those of the Old World; or, recognizing the significance of the historical explanation of our relation to domestication, we may by active and carefully directed research secure results comparable to those of a long period of casual or accidental contact, and obtain a great variety of wild forms for use to meet human needs. Such an example of possibilities seems to be found in the development of the desert rabbit-brush as a source of rubber. An investigation was undertaken as an emergency problem during the World War, when there loomed before us the possibility that submarine dominance would eliminate all possible rubber importations. Recent studies by Hall and Goodspeed have shown the presence of 300,000,000 pounds of rubber in the desert region of the West. At present prices it is not available. In an emergency it might be a factor of first importance contributing to defense of the nation. Future research may also show possibility of large use of this supply through cultivation of the wild stock, thus making the desert an important area of production.

History shows us that sufficient understanding of the natural world about us brings large contributions to human comfort and efficiency; but, in spite of the lesson before us, many feel that the day of discovery of species most useful to man is past.

Returning to the larger view of our problem, the value of ancient history depends on our breadth of interest. If we are to deal only with matters of limited personal or national significance, only for immediate ends, and without reference to other generations; if our democracy is circumscribed in space and time, then lack of perspective and of fundamental laws in history may not be felt. If, on the other hand, we see the impending necessity of full understanding of the world's needs in their present relations and future complications, it behooves us to increase the range of human knowledge and of our comprehension of all factors entering into the problems. To most of us it appears that these great questions require the widest and deepest possible range of human understanding and the labor of generations for their satisfactory adjustment. The world statesman of the future must not only be trained to larger and higher vision, but he must have available an organization of knowledge, perfect in its simplicity and infinite in its detail, covering every interpretable phase of the intricate human problem. As we approach the preparation for this task, we recognize at once the limits of the human mind and of human life, and accomplishment seems realizable only through operation in an altruistic democracy, making possible intellectual cooperation covering a wider range of experience than can be available to the individual mind.

If, in consideration of the larger problems suggested, we assume that man was created as we find him and destined to no higher plane, the sequence of history is of little value. If, however, the evolutionary view of life be correct, the continuity of history becomes of great importance, and origins, however far back, interpret the present. Should we consider that man in his environment is the product of a long series of changes determined by laws laid down in the record of the earth sciences, we have reason to consider, as bearing on the present, every fact leading from the past. In the interpretation of this record we shall view history feeling assured that nothing on the earth or in life stands still, and that this movement means continuous lifting of the plane of the more complex and more progressive.

In the lines which have been read it has been my purpose to indicate the extension of history backward into the earth sciences, and to point out the significance of this sequence as a continuity presenting in its formula an expression of the present. One may not leave the subject without referring also to the possibility of extending this continuing series from ancient geologic time into the future through a span comparable to the past we know.

To one who views the story of the world as presented through the medium of the earth sciences, it must seem unnatural to conceive of the physical and biological forces now in operation as ceasing to act before lapse of many periods like those which we have viewed. Unless there intervene some extraordinary force beyond the reach of our understanding, the laws which have so long defined the course of nature must continue operation. Without the addition of any power beyond the spring of action furnished by laws now working, the clock of the universe must go for almost infinite ages before it runs down.

Just as we are not able to conceive of crustal movements ceasing, so long as we are subject to physical forces like those now controlling nature, so when we visualize the history of life in the broadest sense we are unable to understand how the biological world, if it continues to be, and if it continues in the environment of physical change, can do other than go on to greater extremes of specialization, to greater range of complication, to greater comprehension, and to greater intelligence. If man of the future continues to maintain the relation between mental and biological which has obtained in the past stages of his evolution, there is reason to believe that he may reach to heights of mental ability, of comprehension, of intellect, of understanding, greater than those yet known. What the ultimate goal will be no one may yet see; without fundamental change of governing laws, the movement must go on.

The Geologist's Rôle of Interpreter

One does not expect a geologist to state his own views in philosophy or in phrases aiming at the deeper human understanding, and yet there seems reason for feeling that the wider outlook of science in all of its phases lifts us up to the identical viewpoint from which the philosopher and the poet obtain their comprehensive vision. Unlike the philosopher, we do not reach backward or forward to interpret the final unity and purpose of Nature; nor can we, like the poet, picture in words with fullness of meaning the view which opens to us; but the kind of a landscape which we see and the training of the eye which sees it give to our picture a measure of reality which its stupendous magnitude does not lessen.

Of all favored men, it is the geologist and paleontologist only who see the panorama of ages unrolled in fullest length and in truest reality. To them this record is not written in doubtful hieroglyphs and symbols. It represents the imprints of living feet that have never ceased to advance in unbroken procession over a trail that winds upward through the ages. From one glimpse at footprints on these sands of time, a poet, in the person of Longfellow, gave to all generations a Psalm of Life, which has found response in an ever-widening circle of human hearts. Longfellow's poem, suggested by the antiquity of the print of a foot upon the Connecticut sandstone, was based upon a splendid lesson of analogy. He emphasized for us the idea that the influence of each life may reach out undreamed distances through space and time to make the forlorn and shipwrecked take heart again.

Pointing in the same direction, but of infinitely deeper meaning than the lines of the poet, is the reality of the story, the sermon, the poem which the geologist sees, and which must of necessity reach its recognition through his eyes and its expression through his voice. The footprints and the stages of the path on which they appear are to us not merely evidences of an unending influence; they are tangible proofs of progress from eon to eon which might well help a forlorn world to take heart once more. We may not understand the method by which betterment has come, but we see the stages of its movement, and realize that, whatever struggles the future may have in store, we shall always be credited with a margin of safety when we risk ourselves in the cause which makes for uplist in the widest sense.

Without assuming more than is involved in the field of his daily work, the geologist stands before the world as the interpreter of one view of a great truth fundamental to human interest and belief. This truth should not be overemphasized; it should not be underestimated. It was in large measure this depth of view that stimulated Darwin to his great constructive work, giving biology and the whole range of human thought his progressive evolution. It stands as the background out of which history emerges and against which its interpreted movement must always be projected. The world needs now, as never before, a wide and deep view, and a full understanding of all that may concern mankind. The student of earth sciences was once a contributor to the wider philosophy of nature. It may be his duty now to make sure, not only that his influence is felt in advancement of material welfare, but that he serve also to point out the lesson of the foundations of the earth, and to show that strength may still come from the hills.

THE TEACHING OF HISTORICAL GEOLOGY AS A FACTOR CONDITIONING RESEARCH

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FUNCTION OF THE EDUCATIONAL INSTITUTION IN DEVELOPMENT OF RESEARCH

Discussion of the teaching of any research subject involves preliminary consideration of the position of the educational institution in relation to that of other agencies concerned with the advancement of research. Viewed from the standpoint of one surveying the work of investigation as now expressed in this country, we may divide our greater research agencies tentatively into five groups.

Without assuming to present a complete or exact classification, these are: (1) research of practical application in engineering laboratories; (2) governmental bureaus and laboratories; (3) research foundations; (4) museums and allied institutions; (5) educational institutions. To these five a complete statement would add several of lesser magnitude, among which a very potent force is found in effort of individuals working privately, as has been done to the great advantage of science by many pioneers in investigation.

In order to make clear the position of educational institutions with relation to the other four kinds of research agencies, it is necessary to give an approximate definition of each type.

(1) The expression of research referred to as "practical application in engineering laboratories" includes use of science in development of economic interests in the great variety of ways in which investigation contributes to the good of mankind. The words

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"engineer" and "science" are here used in the widest sense, covering the appliers of knowledge secured by investigation. The operations of this group might be illustrated by the constructor of railways, the builder of aeroplanes, or the dentist. The work of the engineer in all of the fields in which he operates may, unfortunately, be carried on by rule-of-thumb application without consideration of the special merits of each case. The true engineer we all recognize as one who views each problem as a new subject for special study. In a large measure, his judgment must be based upon previous experience with similar studies, but his greatest success comes through realization of the fact that each bridge to be built, whether it be intended to cross a river or only to reach from one tooth to another, presents a special problem not identical with any previously considered case, and that failure to see the individual peculiarities may mean inability to make full use of the principles which are his instruments. The successful engineer is continuously engaged in the application of research methods.

In a still larger sense does the engineer concern himself with research problems by consideration of questions which are not merely specific applications, but involve principles which must be better understood before he is able to proceed. The dentist recognizes that knowledge of microscopic structure of the tooth is of fundamental importance in his treatment of tissues, if this work is to have value in a degree of permanence measured in years or tens of years. The railroad builder realizes that not all rock foundations give real stability to a railway bed, and that an understanding of the material through which he cuts may determine the ultimate value of his constructive work. These investigations in engineering inquiry we often designate as research in applied science. They differ from those in so-called pure science only in the fact that the research of the engineer is specifically directed, and by nature of the inquiry is rather narrowly limited, whereas the real solution of the problem may lie in a rather remote field. The railway builder may find the answer to his engineering questions in special phases of chemistry or petrography which were not included in the curriculum of his training course.

Even with the limitations which are set in investigations designed to meet specific needs in restricted fields of applied science, we must recognize that the every-day operations of great laboratories conducted by far-seeing corporations are developing some of the most significant advances in fundamental science of today. The student of pure science must always keep in close contact with these special researches, both to be helpful and to receive from the engineer the great wealth of data which should be incorporated into the organized body of fundamental science.

(2) Government institutions, as exemplified by the federal bureaus and laboratories of the United States, represent a field which is in some respects intermediate between that of engineers who apply and that of the special students of pure science concerned only with the principles of their subjects. The laboratories of government departments exist for the special purpose of contributing for the benefit of the community. It is necessary that they serve as sources of information for practical applications and for interpretation of the principles of science to the great group of inquiring engineers throughout the country.

Consideration of scientific problems relating to specific community needs leads the government bureau to undertake far-reaching and fundamental investigations in the broadest fields of applied science. Such researches, by reason of the wide range of interests covered, may extend farther than the studies of the engineer or the corporation. As institutions which stand for a continuing people, the government bureaus should be able to undertake inquiries from which results might first become available to later generations. It is unfortunate that budget requirements and responsibilities of political parties tend to limit us in handling of projects which should be continued for long periods or with large funds, for the expenditure of which immediate returns may not be visible. It is presumably true that all science has its application in one form or another, but exceptional vision is required in organization of government work to make it clear that every phase of each investigation undertaken represents efficient application of science for real needs. By reason of its practical limitations, the government organization may lose opportunity for consideration of certain critical problems the settlement of which would ultimately be of great advantage to the state.

(3) Research foundations, with ample resources, freedom of choice in selection of objectives, and with trained men of vision directing their researches, have given opportunity not otherwise available for exhaustive investigation of fundamental problems and groups

of problems without regard to the time required in the study and without reference to immediacy of pressure for application. These institutions have in some measure covered the fields for basic investigation which the corporation engineer and the government bureau could not readily reach. The efficiency attained by these foundations, the vision with which their problems have been selected, and the great contributions which they have made to science, to human thought, and to application of science in everyday life rank among the greatest achievements of American science.

(4) The great museums of America have been strongholds of research in the natural sciences. Their function has generally involved the special study of wide or narrow geographic regions to which they are related through circumstances governing their origin. The museums have also served a most important purpose as educators in natural history, supplementing in a vital way the work of the schools and universities. Through interpretation of science to the great public, the museums have greatly assisted in the effort to make knowledge and reason the basis of our community judgment and to give research the fullest opportunity to serve the people.

In organization of purely research projects the museums have contributed a large share of the material upon which the advance of American natural history has been based.

The work of these institutions is in general characterized by peculiarly close relation to public welfare, both in effective educational work and in the support of fundamental investigations for the sake of their human interest. The museums fill a most important place in the scheme of our research development.

(5) The educational institutions of America, as represented by the universities and colleges, have always had a large place in the advance of knowledge in all of its phases and in its application. Their range of operation in constructive scholarship has been as wide as the limits of learning and its use.

In schools of engineering and agriculture, research has been largely on specific problems of application not differing from those of the engineer's laboratory or the government bureau. Here, as in the departments of fundamental science, the researches have also ranged into all phases of description, organization, interpretation, and analysis in special phases of science for which no immediate application is considered. These activities have been financed in some part by the universities and in part from the pockets of the professors. Considerable support has also come from business interests, from government institutions, and from research foundations.

The university or college includes constructive work as a necessary part of its regular program for at least four reasons, which may be stated as follows:

(*a*) Investigation is an indispensable means of keeping the faculty in a position to present the most fundamental and most advanced knowledge through its teaching.

(*b*) Training in creative or constructive work is one of the most important phases of teaching and can be carried out successfully only through actual experience of the student.

(*c*) The state will naturally depend upon the institution of higher learning as an exceptionally organized group of constructive experts prepared to consider urgent questions requiring investigation.

(*d*) As a body representing a wide range of closely interlocking subjects having continuous relation to research in one form or another, the university affords unusual opportunity for correlation of knowledge on questions in new fields of thought.

In considering the first reason (*a*) we must realize that, even if the universities be assumed to exist only for teaching, they are expected to present the most advanced thought, and we can not keep them in a position of leadership in understanding and in training without a faculty continuously setting forth the best in thought and experience in every subject. This condition can be maintained either by continuous research on the part of the faculty or by continuous renewing of the membership of the faculty. Continuous replacement of individuals is impossible, as the institution is a great and complex instrument in which the parts can be kept in proper adjustment only through long contact. It therefore becomes necessary for the faculty to keep its position by continuous growth of its members. If this process is merely imitative, the teacher is not an authority. The only way in which he can be assured of growth is by working in his specialty. This constructive operation involves intimate knowledge of the fundamentals of his subject and definition of the limits and relationships of his chosen field of study.

More than this, the function of teaching in an educational institution does not concern alone the retailing of facts already assembled;

it must include that kind of understanding of the subject which will prepare the student for his task as a leader in the future. To become such a leader the student must look beyond our present knowledge and experience with the expectation of accomplishing things which have never before been done. No good instructor can avoid recognizing this need of his students. No teacher who sees this requirement can fail to make a serious effort to determine the direction of advance in constructive use of his subject, if for nothing more than to point out to students the trend of the path and the preparation necessary for those by whom it will be extended to new fields of usefulness. It is hardly possible for the instructor to obtain a clear view of future development in his subject without intimate personal relation to the most advanced work in progress.

From the point of view of the student, training in constructive work or in development of creative imagination, suggested in point (*b*), must be considered of importance at least equal to the securing of information or the disciplining of the mind to habits of work. As in no other type of mental attitude, this involves the acquiring of a distinct love of the work and understanding of its purpose. It is not conceivable that the university will neglect this extraordinarily important aspect of the student's preparation for future activity, or that it will expect the student to proceed without guidance. If this particular phase of educational activity is not to be eliminated, it places upon the instructor the requirement that he stand before his students as an unmistakable representative of creative work and as illustrating in his personal attainment the end or purpose of his effort. Evidence of any other attitude on the part of the instructor will make useless whatever attempt he may make to serve as a leader or adviser in the field of constructive study.

The third contribution of value (*c*) furnished by research related to education concerns the immediate use of the results of this study by the community. While the university is naturally assumed to be primarily an educational institution, it has been made clear that without continuing research it can neither provide adequate instruction nor maintain its leadership in the educational work required. Constructive problems in all departments of investigation must be continuously the subject of successful handling, and the results of this work will be products of the first importance to the community. It is natural that to such an institution the whole people will look for the appearance of new ideas of broadest significance and of practical value. It is to be expected that the state will depend upon the university for information and will expect it to furnish the necessary knowledge and the constructive ability required in meeting new situations that make necessary the building of new plans of thought for community use. The contributions made by research in these institutions will generally tend to concern fundamental subjects and to group themselves on the more indefinite areas along the borders of knowledge, but it is frequently these broader principles which offer the largest opportunity for real addition to the sum of immediately useful information.

The fourth reason (*d*) for including research as a part of the necessary program of an institution of higher learning involves one of the distinguishing characteristics of the university. By reason of the extraordinary scope of interests represented in such a body, one might expect the unusual opportunity for contacts of investigators in related fields to produce new combinations of formulæ, and through these the opening of new fields of discovery. No other organization presents the same wide range of subjects represented by leaders of thought who are normally investigators. To these conditions the university adds an unusual freedom of opportunity for choice of materials or combination of materials to be used in investigations, as also the stimulating influence of a continuous stream of students with new inquiries and new ideas. In no other type of institution engaged in investigation are the chances greater for contribution in fields representing either new groupings of subjects or areas which have thus far remained untouched by the workers of all organized departments of knowledge.

For all of the reasons that have been presented, research has now an established place in institutions for higher learning. The position of constructive work in the universities is clearly not accidental, but relates to the generic characters of these institutions.

To the university, viewed as the highest training school, investigation becomes as necessary for natural activity as eating and assimilating are to continued effectiveness of the biological organism. The research so necessary to continuance of adequate instruction we come to recognize as a normal part of the life of the institution, and we look to this kind of an organization in the course of its growth to produce much of value in the forefront of discovery and construction.

The university fails of its mission in creative work in many instances because, of all the types of institutions, it is the most imperfectly financed for this phase of the work which it should naturally conduct. With the clear requirement that, to keep its position in the first line of advanced thought, it must consist of men of the best type in the professions, the university is often financed almost exclusively for teaching and administration without reference to research, and it is assumed that the constructive work so necessary to development of the faculty and students will be cared for in other ways. Beyond funds for purchase of books, departments with large salary rolls for instruction often show almost nothing for constructive work. The ultimate result of this policy must be failure to attain the full measure of efficiency. Under unfavorable conditions potential leaders in the faculty will either find support of their greatest contributions to knowledge outside the institution or, failing in this, they will burn out like a lamp producing feeble light by consuming a wick to which no oil is fed.

The university and college, then, take their places with other groups of research agencies of the country as institutions caring for the initial training of nearly all investigators, and particularly given to wide range of researches among a great variety of fundamental subjects. Their activities in constructive work will often run parallel with those of other kinds of organizations; but breadth of interest, wide range of contact, unusual freedom of relationship, and spontaneity will always be among their characteristics.

Functions of Teaching

Having defined in some measure the position of the educational institution with reference to research, one naturally inquires further concerning the more intimate relation of the methods of teaching to research in the institution. This discussion may be introduced by a brief analysis of the function of instruction as we may interpret it for the institution of higher learning.

The principal objects of teaching in a university or college, as understood by many of us, may be considered as of four kinds: (1) informational, (2) organization and presenting of perspective, (3) stimulative, (4) constructive.

(1) Informational teaching is a descriptive process concerning the transmission of facts which may or may not be available else-

where. There are many cases in which the inadequacy of existing information and the position of the instructor as an expert justify the presentation of data which may not be obtained otherwise. The reiteration of statements already set down in text-books or in other literature easily available may in many cases be of importance because of the touch of personal relation in the presentation. On the other hand, a large part of the information transmitted in purely informational courses may be dangerous to the student, as it inhibits personal effort to go to the available sources for knowledge; and dangerous to the instructor, because it takes his time from other kinds of instruction which may be more valuable.

(2) Organizational instruction begins with masses of fact available and teaches their grouping and use as more or less complicated organized bodies. It represents in some respects a higher use of knowledge and involves a more difficult kind of presentation.

One of the important phases of instruction consists in that type of organization which permits one to see knowledge in the simplest form of statement, and at the same time to realize the infinity of detail and the position of details with reference to the larger principles involved. Not too many individuals recognize the importance of organization of information and the impossibility of effective use of knowledge without understanding the interrelation of its elements. Not a few individuals accumulate vast bodies of detailed information without being able ever to arrange them in such a way as to serve as other than an impediment to advance by reason of clogging of the machinery through the pressure of disorganized and unrelated materials. Others see each subject in its simplest form, and may serve as guides to indicate the direction in which larger movements will go, but are limited in the use of their judgment by reason of lack of relation between general principles and the details through which the principles must in their application be ultimately expressed. One fundamental principle of university instruction involves the larger organization which makes possible a view showing us knowledge perfect in the simplicity of the interlocking parts and infinite as to the details of expression.

(3) The second view of university instruction, which we have just discussed, gives the factors of discipline and order as the most fundamental and significant. Contrasted with this idea, we have the considerations of interest and pleasure in the inquiry into a given subject developed through stimulation in the statement of

the instructor. While it may be true that many students are not worth while, by reason of their constitutional limitations in relation to the subject which they approach or with reference to the particular instructor with whom they come in contact, there can be no doubt that a great number of students also fail because of not having set before them, through the stimulation of clear presentation, the really fundamental ideas basic to subjects in which they might naturally be interested.

(4) Developing the power to do constructive or creative work constitutes the highest object of the student. The ability of the instructor to bring out this quality of mind is the greatest gift. The desire to construct generally arrives most readily through participation in constructive work, and involves the idea of research as a normal part of the program of the university. This view can be presented or suggested in realistic manner only by those who are engaged in actual research. In other words, the institution which fails to give proper opportunity to develop its faculty in constructive work fails to secure the results of highest type in its teaching.

In the statements that have been presented up to the present stage of this paper it has been my purpose to make clear that teaching, as expressed in colleges and universities, serves its highest purpose as training when it develops in the student the ability to see with a true perspective, and to use his subject as a means for constructive effort. At the same time it has become evident that the educational institution is not only the most important molding influence for all future investigators, but that it is itself one of the greatest types of creative institutions, occupying a position distinguished by breadth of interest and by opportunity for contribution to the basic elements of science. Considering its largest usefulness, there is every reason for holding that, whatever else may be included in a university program, the interests of the teacher, the taught, and the community demand that a knowledge of needs and objects for future constructive work and an understanding of the mode of operation of the creative mind shall always be dominant features.

Special Significance of Geology in Teaching Idea of Continuity in Research

What has been stated regarding the problem of the educational institution as a whole applies without amendment to the fields of instruction in geology in all of its phases. I have presented the problem in this general form in order that in further discussion we may more readily express the relation of the teaching of geology to that in other subjects. My desire is to emphasize the point that teaching conducted in such a way as to fail of stress on the constructive element expresses a condition less advanced than that of full leadership and promises for the future a result corresponding to what *has been* accomplished rather than what *should be* done. Geologists have always been a constructive group of scientists, and we may trust that in the further progress of educational work in this field the example of research activities of our distinguished predecessors may serve to establish the method for future advances.

In addition to consideration of the relation of teaching to research expressed in geology, along with all other phases of scientific inquiry, I wish to direct attention to a peculiar relation between the historical phase of geology and other aspects of this science, as also the relation of this aspect of geology to other sciences. It is stated only briefly as indicating an influence of the teaching of this subject upon the general development of research.

Great advances in knowledge are not infrequently made by sudden flashing up of genius opening the way into a new field. Some hold that these individual efforts, unrelated to other researches, represent the normal method of advance of science. Important as these individual contributions may be, careful study indicates that a very large part of the general forward movement is made possible by the fitting of moderate individual contributions into a larger scheme in which the relations of all the parts are known. Through an understanding of the continuity or interrelationship of the facts in the whole field of knowledge it becomes possible to obtain the widest meaning and largest value of each fact. The mind that sees these interrelationships—perhaps through the occasion of having brought a new element into the scheme—is the one that makes the greatest and most useful contributions. This idea of continuity is one which needs large cultivation in science. We may approach it from various directions. One of the most important and most effective means of coming to recognize it is by the historical view. History, interpreted in the truest sense, gives a feeling of broad connections in time and space and origin not excelled in any other field and equaled in few. I am convinced that the wider outlook given by this kind of contemplation is one of the most desirable fundamental elements in the education of a becoming investigator in any subject. We find historical geology giving the grandest of all strictly historical or continuity views. I am confident that the proper expression of this subject in the education program would exert an influence of the wide extent contributing to development of a better understanding of the idea of continuity in science and greatly advancing the interests of research in all fields. I believe that a certain responsibility rests upon the geologist to see that this wider view is sought with increasing interest, and I feel assured that we have large opportunity to exert an influence upon the development of connected constructive thought in the whole education scheme of the great institutions of learning.

THE PLACE OF GEOLOGY AMONG THE SCIENCES

In the early specialization of natural science it seemed relatively easy to give sharp definition to the boundaries of each subject. To-day, as we look upon the continuity of the universe in time and space and action the aspects of knowledge which we call the sciences represent in considerable measure only different points of view.

Seen as a part of the general scheme of things, each so-called science is the point of focus upon which other knowledge is concentrated for a particular purpose. Looking out from the place at which these rays converge it might appear that each subject comprises all the others. So physics may seem the whole of the universe, including life, mankind and human activities. Anthropology, described as man and his works, could compass everything from physics to religion.

Geology, as representing the earth, its structure, its activities, its history, touches science in all phases. It ranges through the physics and chemistry of the earth, its physico-astronomical origin, its expression of current activity, changes of form and face, history of climate and the biological story read from the geological record. Even our basis of judgment regarding the nature of man and his possibilities for the future is indissolubly bound in with the geological story. And yet geology is not all these subjects. It is only that aspect of each expressed in the composition, origin, structure, activities and history of a particular astronomical unit—the earth—upon which we happen to live.

Apart from the centering of attention upon this particular earth, geology possesses marked individuality as a mode of thought, or as the consideration of a special aspect of natural relations, through its expression of the element of time and the significance of movement through it. Lyell described geology as "the science which investigates the successive changes that have taken place in the

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organic and inorganic kingdoms of nature." It stands out clearly among the sciences as the symbol of time and development. In no other phase of knowledge is there a comparable record of events in their chronological order, laid together in such manner that the processes or movements may be made the subject of scientific analysis. In no other science is there comparable illustration of the processes of change or movement or evolution as related to or framed in time.

Important as the developmental or evolutional view has become in science, in general we interpret the materials most readily through the historical process. So in biological evolution the close resemblance in structure of certain birds and reptiles suggests common origin. One assumes a history which would carry the two branches back to remote time where common ancestors might be found. But geology, with its fourth dimension of time, shows us the succession of ages with actual materials left from each in the order of appearance. In ancient mud deposits of south Germany preserving with almost miraculous fidelity the intricate tracing of the insect's wing and the form of the jellyfish, the relationship of bird to reptile is made real by that strange creature, the Archaeopteryx, with long, feathered lizard tail, fingered wings and toothed reptilian jaws, a veritable missing link.

The historical element of geology corresponds to that of archeology in that it is of the order of inference which does not leave room for reasonable doubt. Fragmentary as the remains may be, they are the residuals of materials themselves, and the sequence in which they appear represents the measure of time and of change.

The results in use of this method of examination in terms of time are of incalculable significance to all science and to our thinking as it concerns human problems.

No discussion of structure or history of the earth approaches completeness unless there be included in it an acceptable statement of the origin of the planet in terms of cosmic physics. The attempt to trace the story back to its beginnings is not mere expression of idle curiosity. In the physics and astrophysics involved in the initial development of the earth lie important elements relating themselves directly to the processes and problems of geology as we meet them to-day. Basic in consideration of laws dominant in geological activity must always be that chapter in the story of the earth centering upon studies such as those of Chamberlin, indicating that our planet owes its origin to approach of another star, bringing about partial disruption of the sun and expulsion of a great mass which ultimately formed the earth. In many aspects this phase of geology is physics; in others it is astronomy.

Again, in the story of earth activities illustrated in crustal movement, or in what might be called the physiological process, the principles of physics expressed and interpreted through mathematics become so fully dominant that at times they seem in importance to overshadow the process considered in terms of geology. But we may not forget that even in these investigations the elements of time and sequence and the mode of change become dominant in the synthesis of data which furnishes the ultimate story of the earth.

In a long generation behind us the geological story of life has attained a relatively high level of human interest, suggesting as it does the principle of change or development or evolution through the ages. The nature of the movement, and the process as we see it, might have been worked out through examination of the expression of life in its many kinds or species, or the relation of this differentiation to distribution, or the differentiation and distribution as related to the embryological history of the individual. Yet, with all the data available, the most clearly indisputable evidence of the process which we call evolution is that presented by the record in the rocks.

The aid of geology to biology has been fully repaid by biology through its furnishing of the unreversed paleontological sequence which has been a critical factor in working out the geological time scale for the world. Geological and paleontological correlation, as means for furnishing a complete and fully interpretable record, still presents one of the most important problems of research.

Among the outstanding biological questions toward solution of which geology makes contribution are those concerning the origin and history of man. One of the most important ideas in the range of knowledge is the suggestion that through the ages human kind has tended definitely to widen its opportunity and increase its capacity for understanding. This principle in history so highly valued to-day is made possible largely through evidence from the geological record. One of the elements of especial interest in the geological story lies in the suggestion that of the total record of human life probably more than 99 per cent. comes well within the region for which the geologist is the accepted authority.

The place of research in this particular field of geological history may well rank among the leading possibilities of science. While the investigator rests with assurance upon evidence that to him seems adequate, the great bulk of data still to be expected from research would have enormous influence in making clear to all mankind the idea of change and progress in the longer stretch of history.

Considered from one point of view, we may think of the heritage of man as represented in three elements—the sun, the earth and our machinery for use and development of knowledge. The earth with its story is the objective of the geologist. Upon it must concentrate the most intense study that human intelligence can plan. By definition the geologist becomes conservator of great natural resources upon which life and the future of mankind will in large measure depend. Conservation is not *disuse*—but *which* use shall we permit. Within its program research may well come to have the highest place, with premium placed not alone on discovery of the situation in which a substance is found. The way to use the material to full advantage will also be recognized as of enormous human value.

Recently we began to discover that certain of our biological resources which might soon vanish may be replaced. The reproduction or the synthesis of that which forms the solid earth we have yet to learn. Geology must draw on all knowledge to build its broad foundation even wider. So chemistry and physics and geology will unite to locate and to devise the economic exploitation and the best human use of a wide range of substances of inestimable value to man. In another direction geology and agriculture see the study of erosion and sedimentation as an essential phase of research relating to future use of the arable lands of the world.

And, last of all, among the sciences geology bears responsibility as teacher in a field which is always spread before us in daily life. To some the earth's face never ceases to be flat, and so flat-minded they remain. To others the hills and valleys, through the story of history and building and beauty they present, open a vision of realities which lifts us far above the pettiness of things which in the routine of the day may tend to trouble us.

THE CARNEGIE INSTITUTION OF WASHINGTON

RECENT PROGRESS IN SEISMOLOGICAL RESEARCH

I ought not to refer to Dr. Willis again, but I do wish to say that when I came into the region of the Montana earthquake I had Glacier National Park as my objective, in order to study there a great disturbance of the earth's crust, to which Dr. Willis had given particular attention. I cannot express to you my mental disturbance on hearing at Glacier Park that Santa Barbara had been completely destroyed by an earthquake. I realized that something serious had happened, although I know that reports of complete destruction are usually overstatements.

I come back to the Commonwealth Club, not thinking that I return merely to a preparatory school, as has been suggested, but recognizing that I come back to one of the greatest organizations of this character that we have in America. As I go about the country, I see no group of men which seems to me to represent a higher standard of effectiveness in public service and in discussion of great questions. Your example is one that stimulates other communities. I am sure that in the State of California, with all that it has attained in commercial and intellectual development, you have had a tremendously important part, and that your work will be of increasing importance.

It is particularly interesting to me to come here tonight to hear you discussing the subject of earthquakes, because it is a matter which has been toward the front of my mind for many years, although I have not been a specialist in any phase of the work directly related to seismology or earthquakes. I must say to the President, at once, that I suppose I am one of the greatest sinners, so far as personal relation to earthquakes is concerned. I have always thought it wise to face the question for just what it means.

In many more than twenty years of teaching at the University of California, out of the large classes which went with me into the hills looking over the San Francisco bay, I think you could find many

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"Earthquake Studies," *Transactions of the Commonwealth Club of California*, vol. 20, no. 6, pp. 208–214, September 1, 1925.

who would testify that I said to them that the earthquake had about the same relation to natural development of geological processes that the rain has to development of crops or the growth of plants. I do not like rain, I never did, I never expect to; but I am willing to stand it because we must have rain in order to make crops grow. I do not like earthquakes, I never did, and I never expect to. However, I am willing to bear them for I realize that they have to do with the continuing process of creation of the world as I see it, and with development of those magnificent characteristics which represent California. So I should almost be inclined to consider the earthquake an asset, something that you must have if you desire your hills and your mountains, if you prize the variety of scenery and climate which make California so beautiful.

It is extremely interesting to me to find this discussion of the earthquake in progress, as we are in a period in which all men of science seem to be setting aside the barriers which measure time and space, and to think in terms of past, present, and future as parts of the same movement of unity in nature. When the astronomer tells me that the nebula in Andromeda is something like a million light years away, he means that the light which we see in the telescope left the nebula a million years ago, and that the nebula may be there now or it may not be there; that the continuous line with the nebula at one end and you at the other may exist only in the human imagination.

In other words, your space and your time are inextricably tied together. When you think of evolution, you begin with a very remote past, and develop through the ages a process which brings us up to life today; a process that is interesting to us, not merely because it brings us to life today, but because it concerns also development of life in the future. Go out into the rocks, as I have done, and see there, in a certain sense, the memory of the Creator. There you will find the dramas of Cambrian time pictured as clearly as if they had happened yesterday. We see the process or movement as if the Creator had been preparing the means for us to learn what has happened and from that to judge in some manner what will happen.

So in human affairs today. We are looking into the past, or into history, and attempting by what we learn there to determine the processes operating in the present and what the probabilities are for the future. It seems to me that the barriers of time are being set aside as they probably never have been in scientific thought and in its application to human affairs.

So it is natural that, thinking of the interests of the community in the future, we should sit down to test the facts that relate to the movements of the earth's crust expressed in the earthquake. We wish to know the relation between what has happened and the probabilities of the future. We face the facts as we have never faced them before, with that frankness of the American citizen who knows that, if he has the facts, he may even turn adversity into advantage. I do not know that we shall ever harness the earthquake, but some time some one will perhaps have the thought that, if you cannot stop it, you may not only avoid its dangers but also use it in some way to your advantage.

In my own experience, the study of the earthquake arose, curiously enough, out of another aspect of geological study. I have been concerned with development of life through the ages. I was, in a sense, shaken out of my shell by the 1906 earthquake. I began to realize that perhaps there were voices in the earth that I had not yet understood. I realized that the geology out of which we had been reading the story of life not only represents past ages, but it is, as suggested by that earthquake, a subject which represents also the process in active operation continuing into the future.

So when you take up the study of seismology today, remember that you consider not an incidental or a sporadic thing, but what a biologist might describe as the physiology of the earth, geological processes actually in operation. The seismologist uses his delicate instruments for the purpose of studying what is going on, in order that he may more accurately estimate the value of what can influence us and our civilization in the future.

Let me repeat that I am not a specialist, but my interest in the problem of the earthquake led me, some five years ago, to ask our Board of Trustees in the Carnegie Institution of Washington if there was not something that we might do to help with investigation of a question which is, on the one hand, intimately related to some of the most fundamental problems of geology, and has, on the other side, an immediate and direct humanitarian application. We had only small funds that could be used for earthquake study, but said at least we might begin by inviting a group of great specialists to come together and consider what might be done in the immediate future by co-operative effort. We invited a committee of which Dr. Willis was one of the original members, Dr. Lawson of Berkeley was another, Dr. Ralph Arnold of southern California, Dr. Millikan the physicist, Dr. Anderson of Mt. Wilson, and Dr. Harry Fielding Reed of Johns Hopkins, a distinguished student of earthquakes, were the others. Dr. Day of the Carnegie Institution Geophysical Laboratory, concerned with study of the interior of the earth, was chairman. The committee endeavored to see whether existing institutions, as California, Stanford, Lick Observatory, Mt. Wilson Observatory, United States Coast and Geodetic Survey, United States Geological Survey, the Geophysical Laboratory, and other agencies might not, by their combined efforts, each doing its own part, accomplish some of the things that had not been yet possible in the study of the movements of the earth's crust.

I do not wish to go through the whole story of what has taken place. I must say, before taking up certain details, that the result of combined effort of these many institutions, only with the leadership of a committee, has been, in my judgment, to advance the study of movements of the earth's crust, from the seismological side, as it had not been advanced for many years.

In the development of this study Dr. Willis had an extremely important part. In his promotion of organization in the Seismological Society of the Pacific, increase of its membership, strengthening of its publications, increase of stimulus to research, a tremendous impetus has been given to this work on the Pacific Coast.

When this committee came together it said that there was necessary, first of all, a study of instruments in order that we might secure better records, more detailed information as to what is taking place in the earth's crust than had yet been possible. We have not yet reached completion of the first instrument devised. Several thousand dollars were expended on it in three years. But, while the committee was working on this plan, Dr. Anderson, a physicist at Mt. Wilson Observatory, said: "If you would give us the specifications of precisely what you wish, we could produce it." And long before the first large instrument, so well planned, was completed, Dr. Anderson had furnished a new kind of instrument. The first instrument cost several thousand dollars, and the present seismograph, of a more useful type, can be prepared for much less than fifty dollars without the recording apparatus. The new type of instrument can be tuned to receive different wave lengths, and it will be possible to set up batteries of these recording devices at many points in this coast region so that we shall be able to locate every earthquake, and secure data which had not previously been attainable.

The seismologist, by use of another new instrument, will be able to determine the strains accumulating in the earth's crust and the stresses in the rocks. These new instruments are in process of development, and Dr. Anderson expects to have them ready for our use within the coming year.

The committee said also that we need to know what actually happened in California so far as wider movement of the whole region is concerned. The committee realized that if we invited Stanford University, or California, or any other agency here, to make such a survey, it would cost a large sum. We should therefore invite the proper agency, the United States Coast and Geodetic Survey, to make this investigation. Congress provided the money. The Coast and Geodetic Survey made the survey, with the result which presumably you all know. This survey showed most extraordinary horizontal movements in the crust of the earth throughout the greater portion of middle California and extending down into southern California, movements reaching from two to twenty-four feet within a period of thirty years.

There is a very interesting story that Dr. Willis does not know connected with initiation of the project to resurvey the region of California in which these interesting geographic shifts have taken place. This project came into my office with a project proposing that we appropriate a few thousand dollars for study of a certain hypothesis, to the effect that South Africa and South America were once joined, and have floated apart in the course of some tens of millions of years. I have studied fossil plants and animals occurring in the rocks of South America and South Africa and knew that they were very much alike. I said I was doubtful about the hypothesis suggesting that these continents have floated apart, but knew that something had happened, and was willing to recommend appropriation for use in having South America matched with Africa—and the study was made.

In the meantime the survey in California was begun. They found evidence of a movement from two to twenty-four feet which had taken place within less than thirty years. Now it appears that if a movement comparable to that in California had taken place over large areas of the southern hemisphere, the two continents might have passed each other going around the earth. I do not say that the hypothesis relative to movement in the southern hemisphere is correct. I wish to make clear that I received a suggestion that it is well to be extremely careful about judging adversely on hypotheses that do not fit into your available data.

Other studies that have made California through the existing agencies, and through the co-operation of the committee on seismology, have carried us in many directions. I will not stop to discuss them all. Dr. Willis has much to say on this subject and he speaks with authority. All I wish is to refer again to the fact that there has been set up through the efforts of Dr. Willis and others, a co-operative investigation, involving not merely the question of those disturbances of the earth's crust such as you see in the rocks twisted and bent, wherever you go in California, not alone an investigation of the slipping that occurs for a few feet along a fault line, not merely a study of volcanic phenomena and their effect upon the surrounding earth, nor merely a study of the history of geology, nor any single combination of those phases of this subject which I have mentioned. A co-operative research is set up in which there is being brought to bear all that can be obtained from geology in its various phases, whatever can be secured from the science of physics, whatever can be given through wide range of application of mathematical and engineering studies. And we do not rest there, for the astronomer also makes his contribution, and in that he helps check the location of points on the surface of the earth which have been fixed for us by the surveyor. This is an extraordinary combination or concentration of effort upon a particular phase of geological work. It is characteristic of modern science that such concentrations are giving results not obtained by any investigator alone. The united efforts illustrate what may be brought about in the democracy of science. A great number of major investigations in scientific work must be definitely and closely directed within limited fields. Here is a case in which wider co-operation gives a tremendously important result. That result, let me state again, will be an expression of movement of the living crust of the earth. It will tell us many things that we have not heretofore been able to set down as of the nature of fact. Nobody in California doubts that the crust of the earth has moved, as we find it represented in the rocks, sections of which we see as an everyday experience. Nobody doubts that it moves, if he has felt an earthquake. Nobody who lives in California doubts that the study of crustal movements should be directed toward the earth as it was, the earth as it is, and the earth as it will be. And that is the purpose of this co-operative effort—to learn the actual nature and causes of movements of the outer portion of the earth.

It is not my place to discuss what this scientific study will mean on the humanitarian side, more than to state to you that there is not in my mind the slightest doubt that, as time goes by, we shall come to know the earth well enough to understand the nature of its processes in the past, and what it is now doing. I hear from the specialists that it probably has a language, which in time we shall interpret. I have no doubt that when the results of this work come to be applied on the humanitarian side, we shall be able to determine approximately where, and perhaps roughly when, important movements will take place; that we shall be able to guide the construction of major works of man, and determine what may be built here and what there; and that in the future the engineer, with all the knowledge that will come out of his own researches, will be able to protect us as fully against the earthquake as the builder of the past protected man against wind and rain. In other words, we shall look upon the earthquake as an incident. Californians a hundred years from now will take the view that I have taken with my classes in the study of the rocks. They will be thankful for the hills, will take earthquakes as incidents and prepare for them by use of all the resources of science and engineering, and will not worry about them as time passes.

SYMPOSIUM ON CLIMATIC CYCLES: INTRODUCTORY REMARKS

THE conference on climatic cycles is an outgrowth of discussion on questions touching possibility of a periodic or cyclic element in earth climate. It is assumed that any information making it possible to foresee conditions of climate or of our physical surroundings is of importance.

As the basis of regular routine in living we have already worked out with great accuracy cycles of day and night with varying length of the day. From history and from study of the earth's movements we are acquainted with variation of the seasons. Is it possible that there are dependable periodicities which affect human living but are still unknown?

The presence of periodicities or cyclic movements would not by themselves guarantee the nature of what is commonly called weather. Fluctuations of temperature, of humidity, movements of the air and many other earth conditions we have not yet learned to predict with complete accuracy on the basis of the periodic influences which cause seasons. Other factors related to varying local conditions may affect the swing of general influences in such way as to erase their effect, at least temporarily.

It is recognized that influences upon weather and upon the climate probably derive from a number of sources. We are, however, no longer greatly concerned about effects arising from the internal mass of the earth. In general the influences are seen as mainly external, and principally originating from the sun. But with all that has been learned there is yet much to know regarding variation in solar and other radiation effects. We have also much to learn concerning the way in which the earth receives and, so to speak, utilizes the influences coming from the outside.

In studies of periodicity we are concerned with the factors which have to do with reception of radiation, as also with the nature of

Symposium on Climatic Cycles, annual meeting of National Academy of Sciences, Washington, April 26, 1932. *Proceedings of the National Academy of Sciences*, vol. 19, no. 3, pp. 349–350, March 1933.

fluctuations in the source of that radiation. This symposium represents largely an attempt to present from several points of view the facts regarding radiation and its influence upon the earth.

The paper by Dr. Douglass, on climatic cycles as illustrated in tree rings, illustrates an interesting influence of radiation upon one of the most delicate instruments on the earth, namely, a growing organism recording in its tissues the development of its structure from period to period. The influence of climate upon tree growth is an extremely important problem, and represents one of the most interesting means of registration of such factors. That there is change in plant life due to climate one cannot avoid seeing in development of vegetation at this time of the year.

The paper by Dr. Walter S. Adams, on studies of the sun-spot cycle, presents the evidence relating to variation in the surface of the sun through observation of the sun itself, and a study of the elements involved in these changes.

The paper by Dr. Abbot is based upon study of radiation as it is measured physically upon the surface of the earth. It stands between research on the sun and study of the sun's influence upon the plant.

The paper by Dr. Bowman presents evidence from history of the earth preserved in the geological record. One of the most interesting phenomena of time is the fact that such slight variation of temperature is noted through a period in earth history to be measured in many hundreds of millions of years, and yet in that time there have been fluctuations which marked periods of warm climate in northern latitudes, and glacial climates in what have in other times been relatively warm regions.

The symposium is an attempt to present the results of these types of research as basis for discussion regarding possible further extension of our knowledge of the earth and of the influences which impinge upon life.

NATURE AND EXTENT OF TERTIARY FORMATIONS IMMEDIATELY FOLLOWING THE COLUMBIA LAVA FLOWS OF THE NORTHWEST

Nature and extent of Tertiary formations immediately following the Columbia lava flows of the northwest: JOHN C. MERRIAM. In description of the series of formations in the John Day Valley of eastern Oregon, published in 1901, the writer described under the name of the Mascall Formation a series of deposits in a depression formed by the down-folded Columbia lavas. It was noted that the dip of the lower Mascall is approximately the same as that of the lavas upon which it rests. Reference was made to the fact that the Ellensburg beds of central Washington are probably in part of the same age as the Mascall, and that a similar formation occurs in the Crooked River region to the south. There has been question as to the original extent of the Mascall and discussion of its possible extension over a considerable part of the Columbia lava region east of the Cascades in Oregon and Washington. The purpose of the present note is to call attention to the fact that as studies have been extended by geologists and paleontologists in eastern Oregon and Washington the number of localities representing beds of the Mascall type has gradually increased. It is now important to have a study of the whole area with mapping of the beds of the Mascall stage and careful paleontological determination of the horizons. There is reason to believe that beds of the type of the Mascall may have existed over a considerable part of the Columbia lava region in the latter part of Miocene time. The present occurrences of Mascall may be due to post-Mascall depressions through which certain areas have been subject to relatively less intensive erosion, leaving relics of this formation to be covered in part by later accumulations.

Abstract of paper presented at autumn meeting of the National Academy of Sciences, Cleveland, November 19–21, 1934. *Science*, n. s., vol. 80, no. 2085, pp. 550–551, December 14, 1934.

BRIEF CHAPTERS CONCERNING LIFE OF PAST AGES

THE JOHN DAY FOSSIL BEDS

During the last three or four decades some of the most notable contributions that American investigators have made to science have been based on the study of fossil remains exhumed in the Bad Lands of the western United States. In these strange formations there have been found, scattered through a great thickness of strata, the remains of race after race of ancient animals, all differing more or less widely from the existing inhabitants of the earth. Through a study of these fossils many previously existing gaps in the history of life have been closed up; a flood of light has been thrown upon innumerable scientific problems; and so many new creatures have been discovered that it has been necessary to modify the scheme of zoological classification considerably in order to accommodate them.

Most of these great fossil fields have received more or less careful attention from the traveller and the scientist, but, strangely enough, one of the longest known and most productive of them, the John Day Basin, of eastern Oregon, which furnishes, perhaps, the most remarkable chapter in the ancient history of the earth, has remained practically unknown, excepting to the few who have actually visited it.

Like many another rich field for scientific investigation, these fossil beds were discovered by a military expedition. In 1861 a number of fossil rhinoceros teeth, in the hands of army officers returning from a campaign against the Indians, attracted the attention of Professor Thomas Condon, then pastor of the Congregational church at The Dalles, Oregon. He perceived that a great discovery had been made. In the following spring he obtained permission to accompany a party going out to re-enforce troops that had wintered in the field, and under military protection he made a reconnoissance tour through the principal fossil localities, but was prevented by marauding Indian bands from collecting many specimens.

Harper's Monthly Magazine, vol. 102, no. 610, pp. 581–590, March 1901.

Some time after the discovery of the field a number of bones and teeth were sent by Condon to Professor Marsh, of Yale, with the result that Marsh came out post-haste, and having satisfied himself of the importance of the discovery, engaged several collectors, who were employed by him interruptedly for many years. Following the example set by Professor Marsh, many prominent institutions of this country and of Europe have worked over the beds, obtaining the remains of a large number of strange and interesting animals previously unknown.

But for the existence of the John Day River, we would know little regarding the ancient life of eastern Oregon, for great lava floods have covered almost the entire country, burying thousands of feet deep all but the later geological formations. As the result of long ages of erosion, the John Day has cut a deep and narrow valley, which passes through the lavas, and exposes to view, layer upon layer, in almost diagrammatic arrangement, the formations above and below them. In the strata of this section we find entombed the remains of those venerable creatures which attract the scientist to this field; and written, as it were, upon the walls of the great mausoleum, we discover the record of a remarkable series of changes in the physical geography of the country, that occurred in the ages during which these animals inhabited it.

In the erosion of their cañons the John Day and its tributaries have uncovered about ten thousand feet of strata, comprising eight or more geological formations, which represent as many distinct periods in the history of the country. At the bottom of this enormous pile are masses of ancient crystalline rocks the age of which is yet unknown. The lowest well-known strata are two almost inseparable formations, aggregating not less than 3500 feet in thickness. They contain numerous fossil remains which are all of marine animals, and demonstrate the existence of the sea over this region at the time they were being deposited. The lower formation is mainly hardened mud, indicating rather deep water, while the upper one is principally sand and coarse gravel, showing that the sea was shallowing as it accumulated.

The Cretaceous period, to which this, the first legible record in the history of this region, is carried back by these lower formations, though by no means early in geological time, is so remote from the present that it is difficult to measure its distance, except by the magnitude of the changes in the earth and its inhabitants which have taken place since it began. Perhaps the best illustration of this, from the physical stand-point, is found in the fact that at the beginning of Cretaceous time a considerable portion of the strata which now form the Himalayas, the Alps, and the Rocky Mountains were not yet even deposited, as gravel, sand, and mud, on the floor of the ocean; while to the long period required for their accumulation we must add the time necessary for the elevation and sculpturing into their present form of these enormous masses of material.

Though we find no remains of land animals in the Cretaceous beds of the John Day, we know from a study of other deposits of the same age that the dominant animals of this period were gigantic, fantastic, reptilian forms, quite unlike anything living at the present day; and that the mammalia, which played such an important rôle in the later John Day life, were represented in the Cretaceous very sparingly by insignificant creatures.

Following the close of the Cretaceous period, during which the fires of the earth were slumbering, there was inaugurated in the John Day region a long era of vulcanism, extending almost up to the present day. In this age volcanic and other igneous activity seems to have been almost continuous in or around the basin, and there were accumulated about 6000 feet of strata, consisting principally of lava and volcanic ashes. The four or five hundred feet of hardened ash and tufa at the bottom of the section are known as the Clarno formation, of Eocene age, and constitute one of the unique scenic features of the valley. Wherever they are exposed, these strata weather very unevenly, producing numberless grotesque balanced rocks and mock statues. Resting upon the Eocene in the river cañon are nearly two thousand feet of soft, fancifully sculptured and pinnacled, and often beautifully colored, ashy beds, designated as the John Day Miocene. Upon the crumpled surface of this formation lie the great Columbia lava beds, three thousand feet thick. Above the lavas are eight hundred feet of tilted ashy strata, the Cottonwood formation, of Pliocene age; and upon these, in nearly horizontal position, are about four hundred feet of coarse gravel and volcanic tufa, the Rattlesnake beds. In the river valleys, which are necessarily younger than the strata into which they are cut, we find, on terraces about fifty to seventy-five feet above the stream, the ashy and gravelly remnants of the last deposits formed before the present period.

All the formations of this age of fire contain fossils, but in none of them do we find shells or skeletons of marine animals. The remains are all of land or fresh-water forms, which signifies that the shallowing Cretaceous sea disappeared entirely from the region before the beginning of the following period, and that the later strata were deposited either in fresh water or as ash drifts or flows of mud and lava upon the land. Judging from the character of these deposits, they are generally considered as having originated in large lakes. We have evidence of the existence of four of these inland seas, in which showers of volcanic ash, streams of volcanic mud, and the natural wash from the land, heaped up, layer upon layer, great deposits, the remains of which we now recognize as fossil lake beds in the Clarno, the John Day, the Cottonwood, and the Rattlesnake formations.

Some of the lakes seem to have extended over large areas. Scattering outcrops of these deposits are found over a great portion of eastern Oregon, indicating at least a correspondingly wide extension of the ancient seas. The relations of the strata of successive deposits to each other show that the bed of the Eocene lake had apparently been dry some time before the waters of the John Day lake began to gather. We know also that the second, in turn, was dried up before the first eruption of the Columbia lavas, for we often find in the bottom of the lower lava beds the charred remains of forest trees, which thickly covered the upper surface of the John Day formation when they were overwhelmed and buried by the first flows.

The Columbia lava formation, as we find it here, is one of the most remarkable products of igneous activity which the world has known. Varying from fifteen hundred to three thousand feet in thickness over an area of approximately 200,000 square miles, it represents an enormous mass of molten material removed from beneath the earth's crust and poured out upon its surface. It was not, as has sometimes been supposed, due to a single great volcanic outburst, but is composed of a large number of small flows that were apparently poured out at intervals during a long period.

Little is known as yet regarding the sources from which the immense quantity of lava and ashes in eastern Oregon has been derived, or of the vents through which it came to the surface. The magnificent volcanic cones of the Cascade Range to the west, which would naturally be considered as the source, are not of sufficient calibre to furnish all this erupted material, and are, moreover, of later age than part of it.

Beneath the lava the strata are in many places broken or faulted by many great fractures, and into some of these the molten basaltic material has been squeezed, forming dikes. The Davis dikes, crossing the main John Day River near the junction of the North and South forks, extend, with some slight interruptions, for about fifteen miles as a well-marked wall of basalt many feet in height. Though it has not yet been possible to connect the dikes with the flows above, it is pretty certain that the great laval masses are the result of what are known as fissure eruptions, or the squeezing out of vast bodies of molten material through wide cracks in the earth's crust.

Where it has not been cut through by streams, the Columbia lava now covers the whole of the John Day country north of the East Fork as a nearly horizontal sheet. Along the northern side of this valley it bends down sharply, passing beneath the river-bed, and in this depression rest the strata which give us the next chapter in the history of the region, namely, the deposits of the Cottonwood lake. These beds, as well as those of the Rattlesnake formation just above them, are tilted in the same direction as the lava, indicating that the sinking of the lake floor was continued through a long period, the last subsidence having given a slight slope to the uppermost strata. Deposits similar to those of the Cottonwood and Rattlesnake lakes are found at other localities in eastern Oregon, and a number of large bodies of water probably existed here on a wide lava plain in Pliocene time.

One incontestable proof of the great antiquity of even the uppermost strata of the John Day section is furnished by the cañon-cutting of the rivers, which is perhaps the most striking thing in the average landscape of the basin. Everywhere the narrow valleys show on either side the edges of similar beds that were evidently once connected. This means that the great gorges have been formed since the deposition of the uppermost strata through which they cut. That many millenniums would be required by the streams in scouring their way through the adamantine lavas and into the formations below, at the most rapid rate at which they wear, is evident to any one who looks into the chasms that are the result of their work. An interesting confirmation of the evidence supplied by erosion is found in the occurrence of remains of the mammoth, and other animals now long extinct, in the terraces near the bottom of the valley. These deposits, with the included remains, are stranded remnants of stream wash, formed when the excavation of the gorge had advanced almost to the present stage.

The purely physical history of the John Day Basin is in itself a subject of absorbing interest. The kaleidoscopic changes in the geological record present to us in succession over the same area the deep waters of an open sea, an alternation of great lakes and dry plains, an ocean of molten stone, a second series of alternating lakes and plains, and finally the existing landscape, cut by persistent abrading of the streams out of the débris accumulated in preceding ages. All this shows plainly that the physical features of the earth's surface, which serve as our symbols of the everlasting and unchangeable, only appear permanent because the range of human observation is limited to a mere moment in the long stretch of geological time.

To a student of living things, these physical revolutions are, however, only changes of scene in the history of the creatures which have inhabited this region. His chief interest centres on those living beings which kept the flame of life alive through these long ages.

The history of the ancient inhabitants of the country is furnished us by the remains entombed in the strata of successive periods at the time of their accumulation. The majority of the fossils found are single bones and teeth, or parts of skeletons which apparently lay for a long time upon the land before the scattered and decayed fragments were carried into the lakes, a few at a time, by stream or rain wash, and buried in the slowly accumulating deposits. In many instances the bones have evidently been torn apart and broken by beasts of prey; in other cases they were almost gnawed to pieces by small prehistoric rodents, which left indubitable evidence of their work in the innumerable marks of their sharp incisor teeth. Occasional entire skeletons discovered are probably the remains of animals which were drowned or mired in the lake, or perhaps were overtaken and buried upon the land by ashes or mud from volcanic eruptions.

The collecting of fossils in this region has about it a fascination that is, in a manner, a combination of the passions of the hunter and the miner with the natural inborn desire to learn of something entirely new. The danger that one experiences in climbing over steep and treacherous places on the cliffs in search of specimens, and the unquenchable hope that each projecting fragment encountered may prove to be a part of some fine skeleton, are sufficiently strong to raise the otherwise tedious and laborious occupation far above the level of drudgery. Whole skulls or portions of skeletons are occasionally found almost freed from the rock by erosion, and the pleasurable excitement felt in coming suddenly upon such treasure, after perhaps many hours of fruitless search, is not exceeded in the securing of any other variety of game. Usually there is exposed only a very small portion of a bone, which has, through weathering, come to look so much like the surrounding rock that only the most careful scrutiny of the exposed strata will result in its discovery. When the large Elotherium skull now in the museum of the University of California was found, only a portion of a single dingy front tooth was in sight; and not until several days of hard labor had been expended in cutting away the surrounding rock with pick and chisel was it at all certain that the whole cranium was present. The skull was situated in an almost inaccessible place near the top of a steep bluff about two hundred feet high, and in order to get standing-room from which to work, it was necessary to cut foot-holes. To make matters worse, the cranium ran straight back into the cliff, necessitating so much excavation that a number of loose blocks above were almost certain to fall and damage it. To avoid all possibility of accident, steps were cut to a pinnacle about twenty feet above the specimen, and from that point the face of the cliff was systematically torn down till a working space was uncovered. The whole operation of excavating occupied for two weeks as many persons as could conveniently work at the same time, and resulted in the discovery of the most important parts of the animal's skeleton. The lower jaw was found intact some distance away from the cranium, one of the fore limbs and a few scattered bones were beneath the head, and close behind it were all of the neck vertebrae.

So many specimens would seem to be discovered by pure accident that one learns to examine the rocks with all manner of possible occurrences in mind. Although digging blindly into a cliff for fossils is generally about as fruitless an expenditure of energy as would be harpooning at random into the sea for whales, the collector never neglects to explore for some distance around the hole from which a skeleton has been removed, as many of the finest specimens known have come to light in this way.

On one of the California expeditions the writer discovered a nearly perfect head of a three-toed horse resting on the brink of an excavation made by some earlier expedition. Probably the picks of the first collectors had cut within a few inches of the skull, which was not then uncovered by erosion. After removing the horse head, a stroke into the surrounding matrix jerked a perfect wolf skull entirely free from the rock.

The explanation of finds of this character is found in the fact that the skeletons seems actually to be in pockets or nests, where they may have been brought together by currents in the lake.

The remains found in the lake beds represent the most common animals of their time. Then, as now, only one skeleton out of many thousand would be buried, even in part, in such a way as to insure indefinite preservation, and the chances of rarer forms being thus entombed would be very slight. The fossils in the John Day beds proper, where they are more abundant than elsewhere, pretty certainly furnish us a fair picture of the dominant life of eastern Oregon in Miocene time. Probably the total variety of animals that have so far been found there is about what a prehistoric hunter would have encountered in the flesh on an excursion of a fortnight's duration about the John Day Lake.

The known remains from John Day strata include the leaves of a few types of trees, a number of snail and clam shells, many large tortoises, a few birds, a snake, a lizard, and a large number of mammals. These last forms are by far the most abundant as well as the most interesting fossils. Compared with the existing fauna of this continent, the mammalia from these beds are indeed a strange assemblage of creatures. None of the species are living now, and even the majority of the sub-families are extinct.

At least three-fourths of all the material collected consist of remains of certain peculiar hoofed animals known as Oreodons, curious forms which do not closely resemble anything now living, though they are related to the deer and the hogs. Possessing grinding teeth somewhat similar to those of the deer, they had also prominent tusks developed on both the upper and lower jaws as weapons of defence. The numerous species varied in size from that of a dog to the dimensions of a small cow. Several skulls of the giants of this group, that have been examined by the writer, are at least seventeen inches in length, and must certainly have belonged to large and powerful animals. The Oreodons probably roamed over the hills and along the shores of the lake in small herds like the deer or sheep of later ages.

Not so common as the Oreodon bones are those of a small horse about as large as a sheep, which, from the absence of any visible means of defence, must have trusted to his slender, three-toed limbs to keep him out of danger. In constantly standing or running on the tips of his longest or middle toes, he was obtaining from his limbs the highest possible degree of elasticity and speed, and was at the same time losing the use of the side digits, and developing the one-toed type of foot which we find in his living relatives.

The largest animals yet discovered in the John Day beds are the giant Elotheres, relatives of the living hog, ranking among the largest known mammals. The skull of the specimen at the University of California measures about thirty inches in length, and numerous fragments of other skeletons indicate the existence of much larger individuals. Judging from what we know of the skeleton, the Elotheres must have attained a length of over ten feet and a height of six or seven feet. Probably few animals have ever existed that were better able to protect themselves than these huge Miocene boars; yet they have long since disappeared from the earth, leaving no direct descendants.

No less strange than the creatures that have been mentioned, appear to us the ancient representatives of several groups of animals which now inhabit parts of the earth remote from Oregon. Remains of near relatives of the rhinoceros, the camel, the tapir, and the peccary are well known from these deposits. The rhinoceros is now confined to the Eastern Hemisphere, the camel tribe is represented in the Eastern Hemisphere and in South America, tapirs are found in southeastern Asia and South America, and peccaries are at home in South America, though they range into southern United

States. All this goes to show that the present distribution of animals has no more been permanent from the beginning than were the physical conditions in any given locality.

Preying upon the weaker hoofed animals were numerous flesh-eating forms, of which we find remains not uncommon. Wolves are represented by more than a dozen species, and the cat tribe by eight forms belonging to the family of sabre-tooths. In these cats the upper canine teeth were greatly elongated, flattened, and serrated along the edges, making the most formidable weapons ever possessed by any carnivore. Some of the sabre-tooths were much larger than the living puma, and probably preyed upon all the other mammals, excepting the larger species of Elotherium.

The teeth of these carnivores, as well as of all the other mammals, are usually preserved to us practically unchanged, not only in form, but in the materials which compose them. The worn surfaces which we find on the murderous teeth of ancient wolves and sabre-tooths are the actual surfaces which clicked together when they tore through quivering nerves and muscles. The glistening enamel surface which we find on the sabres of the great cat is the same that dripped with the blood of Oreodons and three-toed horses so long ago that the mountains of eastern Oregon have no recollection of the day, because they were then unborn.

The fossil forms of the Cottonwood lake beds are not only very different from the animals living at the present time, but they are also unlike those of the John Day period. So far as the writer is aware, not a single species of John Day mammal survived the period of Columbia lava flows and left remains in the deposits of the Cottonwood lake. This does not necessarily mean that every living thing was overwhelmed and buried in the lava, though doubtless many perished in that way, but rather that the time which elapsed between the two lake periods was so long that before its close the accumulated changes by evolution and the immigration of new types of animals from other regions had resulted in the complete alteration of the mammalian fauna.

In the interval during which the paleontological record was interrupted, the pigmy three-toed horses had become very rare, their place being taken by a larger form, in which the side toes were relatively much smaller. In the ashy beds at Cottonwood we find teeth and scattered bones of this interesting animal quite common. In the museum of the University of Oregon there is from this locality a perfect foot, which served as a basis for part of Professor Marsh's famous work on the evolution of the horse. The little camels of the John Day are also replaced by much larger forms, which are more common than their predecessors. The Oreodons had nearly disappeared, and their bones form only a small part of our collection. Elotherium remains are unknown in these strata, but in their place we find another giant, the mastodon, the oldest representative of his race in this country.

In the strata of the next section of the geological record, the Rattlesnake beds, we find fossils of a still higher type than those from the Cottonwood lake beds, but the change in the fauna is not so great as that which occurred during the period of Columbia lava flows.

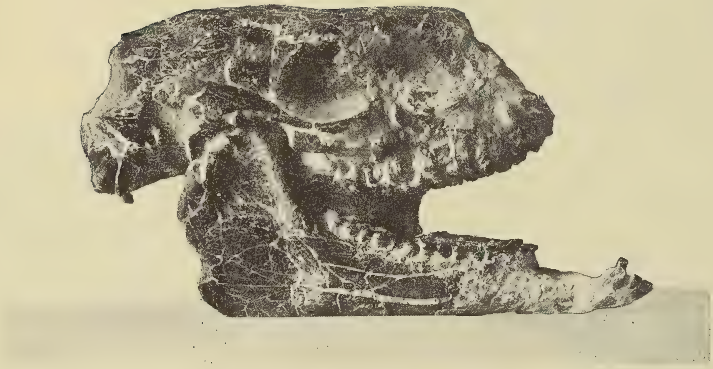
Along the John Day and other rivers of Oregon, in the many remnants of ancient stream deposits left stranded on the sides of the valley as the river channel deepened, we find fossil remains which tell of still another, later, but distinct, period, in which the life of this region was different both from that of the age preceding and from the fauna of the present day. In these terraces are found foot bones of horses closely resembling the existing domestic animal, but still a distinct species. In the same deposits are fragmentary skeletons of gigantic cattle, compared with which our Texas steers would seem quite diminutive. Associated with the remains of these animals, which foreshadow the fauna of our own time, are the bones of a gigantic sloth, a grotesque creature entirely different from any beast now living. Some years ago there was found in these deposits, near Cañon City, Oregon, a nearly complete skeleton of an extinct elephant, with tusks, skull, limbs, and vertebrae in almost perfect condition.

The occurrence of the great sloth and the elephant in these deposits shows us that as late as is this period, compared with the many preceding, it is still so remote from the present as to be entirely beyond the range of human history and tradition.

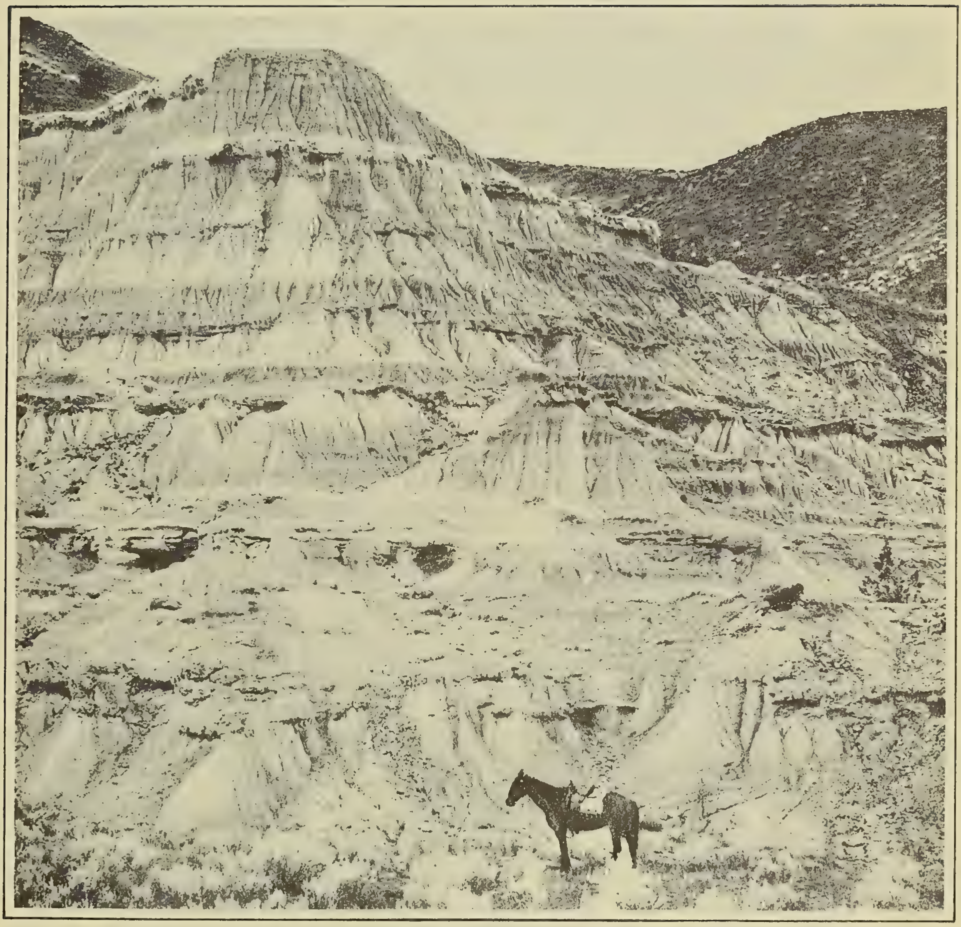
The few typical examples that have been given of the fossil contents of consecutive formations present, as it were, the record of a succession of organic worlds, each specifically distinct both from those preceding and those following it. Early investigators in Europe concluded, from a study of faunas similarly related, that the geological history of the earth was made up of a series of periods of quiet with abundant life, alternating with universal catastrophes in which everything organic was destroyed. Each period was, in a manner, an experiment of the Creator in His search for the highest types of creatures. The general aspect of the life of each formation is, however, more like that of the present than is that of the beds below it, showing a gradual advance along definite lines. In some cases, as illustrated by the horse and camel tribes, the stages are of such a character as to leave no room for doubt that a blood relationship existed between forms of succeeding periods. We find, further, that in each formation the fossils of the uppermost beds differ materially from those in the lower ones, which means that considerable changes were taking place while the record was being made. The physical history of the region, as already indicated, shows us that the strata of the successive formations are not a continuous record, but that long intervals may have elapsed between the periods of their origin. The fossils of consecutive formations we therefore consider as recording *stages* in the history of an uninterrupted chain of living forms stretching from early geological time to the present day. The remains in a given series of formations are not necessarily all in a direct line of descent, for shifting currents of migration frequently changed the entire fauna of each region, bringing to it new life from other lands. The conclusion of each cycle, however, always finds the average life higher than at its beginning.

Although there are other geological sections, particularly in western United States, which furnish as remarkable a history as that which has been barely outlined, there are probably none in which the relations of the various chapters to each other are more evident than they are in the record inscribed on the walls of the John Day Cañon. The deciphering of the geological story of most regions is accomplished through the enthusiastic labors, over wide areas, of men taught to see things which escape the notice of untrained observers. The John Day section tells its story so plainly that to one who sees the record a comprehension of its meaning is unavoidable. Standing above the Picture Gorge, a magnificent cañon near Cottonwood, one may see, marked out with almost diagrammatic clearness upon the valley slopes, nearly the entire series of formations. From these strata were obtained the greater number of the fossils mentioned in this outline, together with many others no less interesting, and the succession of faunas is here splendidly illustrated. Probably nowhere in the world does the scientist work amid more impressive surroundings than in this valley, where every cliff has blazoned upon it the proof of such immeasurable antiquity of the entombed remains. To one who reads this record as it stands, an undisputed work of the Creator, there is made a revelation no less magnificent in its expression of historic fact than that in the creation story of the books of Moses.

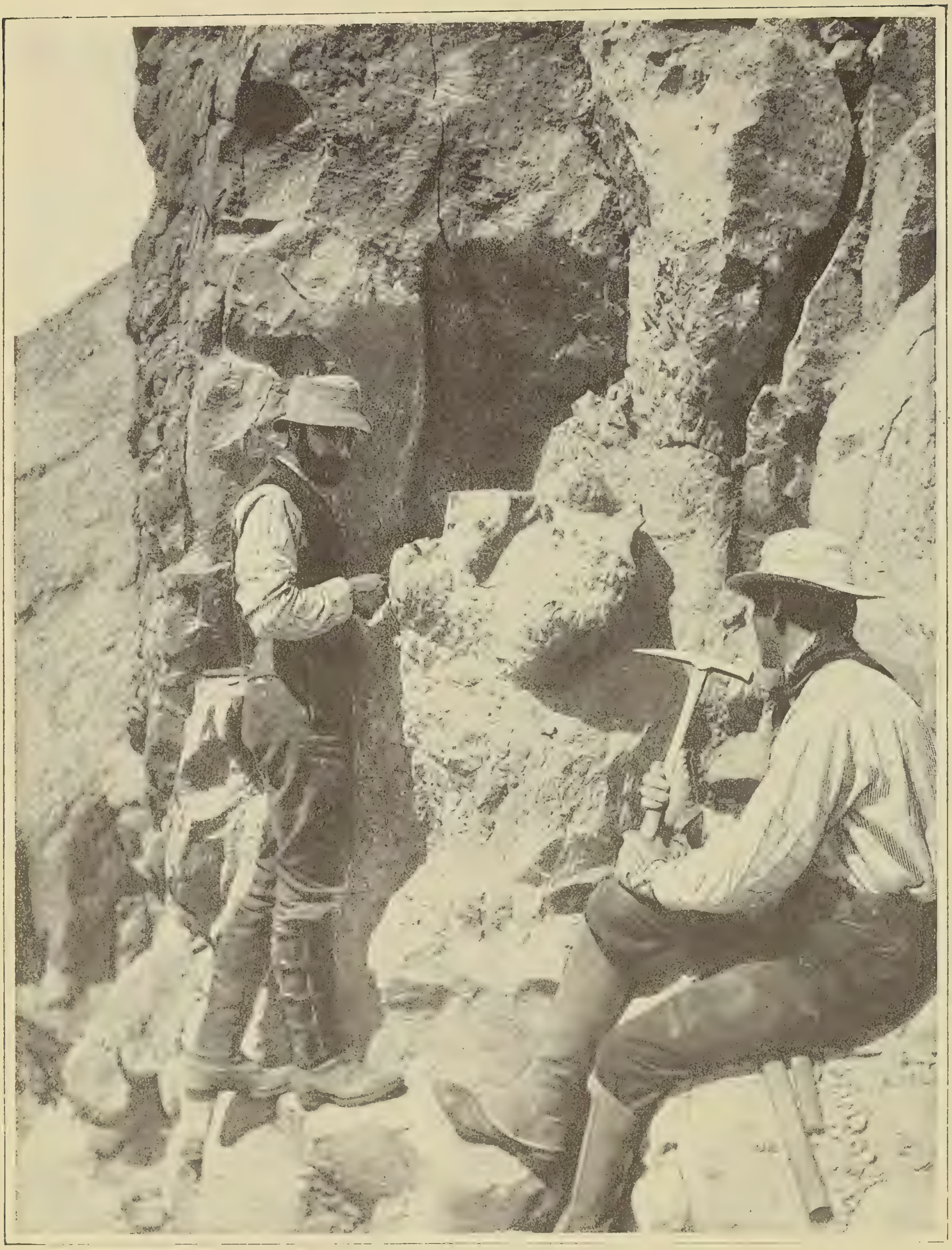
A view in the John Day Region



Skull of three-toed horse

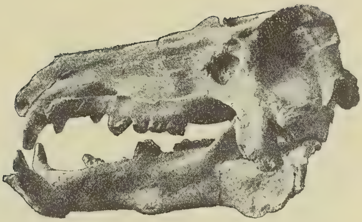


Digging out a camel skull

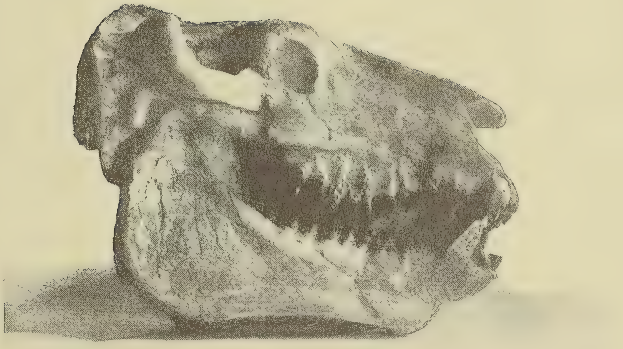


An Important Find

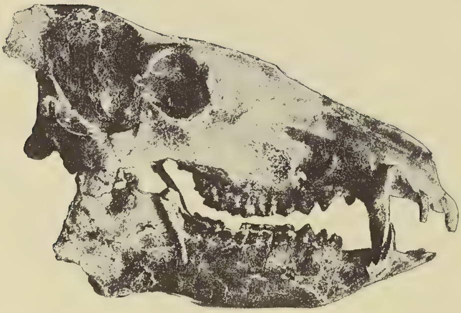
Cutting out of the rock the cranium and lower jaw of a large Elotherium



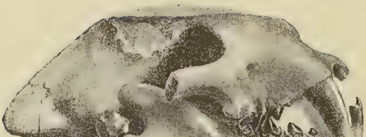
Elotherium skull, Bridge Creek. Length of skull about thirty inches



Skull of large Oreodon



Skull of peccary from John Day fossil beds



Skull of sabre-tooth tiger

DEATH TRAP OF THE AGES

SABRE-TOOTH TIGERS, GIANT SLOTHS, MAMMOTHS, MONSTER WOLVES, EXTINCT CAMELS, HELD FAST IN A HUGE TAR POOL NEAR LOS ANGELES—TRAGEDIES OF AEONS AGO

A PATHETIC PAGE FROM THE PREHISTORIC PAST

DR. MERRIAM OF THE UNIVERSITY OF CALIFORNIA HERE TELLS A STORY THAT IS INTERESTING SCIENTISTS THE WORLD OVER

Editors' Note.—Here are given for the first time details of a discovery of absorbing value to science; a story, too, of fascinating interest to any reader, not only for its revelation, but for its direct reaching-back some tens of thousands of years. In an asphalt deposit south of Los Angeles, scientists have found, recently, perfectly preserved fossil remains of many prehistoric animals—bones that tell wondrous facts in the history of creation. Geologists turn earth's pages for knowledge—here they have found a three-volume novel. This sticky pool of water and tar has been a Death Trap of the Ages. Here for centuries, evidently, the enormous ground-sloth and other clumsily moving creatures of his kind came for water, only to be held relentlessly; herds of bison and horses were entombed, extinct forms with whose bones mingle those of the mammoth and the camel. To this helpless prey, snared for them in this bird-lime bed, came the lords of that era, the huge sabre-tooth tiger and the monster wolf, the largest of the dog family. Trapped in their turn, they, too, fed the black maw of the asphalt pool and the death trap baited itself anew.

To-day the records of that ancient death drama are disclosed. No less than seventeen perfect skulls of that tiger, with its huge knife-like tusks, have been uncovered thus far, beside at least one complete skeleton, while forty perfect skulls of the wolf have come to the light; all these were found in only two cubic yards of material. Heretofore, scientific students of the sabre-tooth tiger have been forced to limit their observations to a comparatively small amount of material, and the only known remains of the great wolf consisted of a few teeth found in Indiana and Texas, and a fragment of a lower jaw in the California Academy of Sciences, before the San Francisco fire of 1906. The writer of the accompanying conservative story of this great geologic find sought, before the disaster, to learn of the whereabouts of the wolf teeth that he might place them in the same collection

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with the jaw-bone, but they could not be traced. Then came the destruction of the Academy specimen, and the investigations of Dr. Merriam remained as the link between the lost evidences and this remarkable discovery in California.

The geologists first heard of these fossil treasures through information that certain asphalt near Los Angeles was considered refuse because it contained large quantities of animal bones. No one then knew that these perfectly preserved fossils were older than history. In these remains Dr. Merriam found several of the long-sought wolf teeth, and now he has a collection in this university museum that is the envy of all his co-workers. So well preserved are all the bones that the scientists for a long time could not credit the theory of their age, but the proofs are unmistakable. All such animals were extinct aeons ago. Evidently the burial in the asphalt resulted in perfect preservation. Even specimens of insects, of a character unknown in the books of modern entomologists, are found here in this cornerstone of world-old records.

Only the facts, plainly stated, are here given. The value of these discoveries to the scientific world is such that the many delvers in such mysteries of the past are watching with keen expectancy the progress of the excavations now being conducted by the University of California. The location under examination is along the line of railway between Hollywood and Sawtelle, and is about a square mile in area. Strange it is to note that the Death Trap is still set. Every day the treacherous pool catches a crane or duck or smaller bird, holding them tight in sticky grasp, and laying them away for the wonder of some paleontologist of the unguessed future. The remains are not far from the surface and close by the pool that forms to-day's trap. While some intimation of these discoveries has been given to science through a brief report by Dr. Merriam to a scientific journal, this is the first authentic detailed narrative to be published. Further reports will be delayed until ample time has been given Dr. Merriam and his associates, E. L. Furlong and Felix T. Smith, to study out hoped-for results from the fossils found and to search for more remains of these creatures that covered the western landscape in the days of the long, long ago.

And meanwhile, as these men of science go on exploring the black secrets of this almost dateless prison, though they say little about it, their eyes are ever open for the possible find of finds—some trace of the companion of this giant sloth, the contemporary and destroyer of the sabre-toothed tiger and the gigantic wolf—Unrecorded Man!

> Ung—hath he slept with the aurochs—watched where the mastodon roam—
> Spoke on the ice with the bow-head—followed the sabre-tooth home?
> —Kipling.

A few miles west of the city of Los Angeles, there is situated an extensive deposit of asphalt which has been largely quarried for commercial purposes. It has been known for many years that certain portions of the asphalt contain large numbers of bones; and skeletons were found to be so numerous in some places, that in quarrying it was not profitable to attempt the separation of asphalt from the layers in which they occurred. The bones appeared so fresh and well-preserved, and were so near the surface of the ground, that there seemed to be little reason for considering them as other than the remains of domestic cattle, sheep, horses, dogs, and other animals, and the attention of investigators interested in prehistoric life was not attracted to them. Only very recently has it become known that the skeletons present in such numbers represent many strange, extinct animals which lived in an earlier geological period, and that the asphalt beds at this locality form one of the most remarkable accumulations of prehistoric remains in the world.

The asphalt deposit lies in an open space between two groups of derricks marking important oil belts immediately to the north and south. In this area almost pure asphaltum forms the surface of the ground, or is only a short distance below it, over about a quarter of a square mile. Other deposits extending interruptedly to the east, and reaching well within the thickly settled portion of the city, would probably add not less than half a square mile to this area. At numerous points bitumen has recently been oozing out over the surface, outbreaks of this nature occurring in many places as puddles connected with little crater-like vents. Near the middle of the area is a lake or pond bordered by quagmires of soft asphaltum. The water of the pond is heavily loaded with oil and tar, and through it great gas bubbles several feet in diameter are constantly rising with a loud splash.

Extent of the Deposit

According to the geologists who have most carefully studied the asphaltum beds of this region, they are located immediately over a sharp fold in strata which have been heavily impregnated with petroleum. At the summit of the fold the strata have been broken up to some extent, and for a long period small quantities of oil and gas have been seeping out and passing to the surface. As the oil passed upward, the lighter portions disappeared through evaporation, and the residue formed tar springs and pools. In the course of time, the tar has dried and hardened locally to the consistency of asphalt. This accumulation continued until the great deposit exposed here had been formed. What the actual thickness of the beds is has never been determined, but the bottom is not reached in quarrying to a depth of fifteen feet.

Scattered Bones and Teeth

In many places where the asphalt comes to the surface, scattered pieces of bones and teeth are seen in it. Where cuts have been made in quarrying, some sections show bones scattered irregularly through them. In other places certain layers will be found nearly barren of remains, while other fairly defined strata show a mingled mass of bones, and pieces of partly lignitized wood in a matrix of pure asphalt.

The skeletons are all remarkably fresh and well preserved, and excepting a deep discoloration by the asphaltum, they are hardly to be distinguished from those of animals recently killed. In cases where the fossils are exposed on the surface they may be mixed with bones of modern sheep, cattle and horses; and it is not remarkable that all were at first considered to be of recent origin.

In the collections that have been made in the asphaltum up to this time, quite a variety of creatures are represented, of which the great majority are mammals and birds. Of birds there are many kinds, among which ducks, geese, pelicans, and eagles and condors are recognized. The smaller mammals include mice, rabbits and squirrels. The larger members of the mammalia are represented by extinct species of coyotes, gigantic wolves, bears, sabre-tooth tigers, horses, bison, deer, camels, elephants and large sloths of an extinct group. Beetles and centipedes have also been found, and doubtless many other animal forms are there, but have not yet been recognized.

Two Extinct Wolves

One of the most common animals in the asphalt is a large wolf, one of the largest members of the true dog family known among either living or extinct species. Associated with it, though relatively rare, is a smaller wolf closely related to the existing coyotes. The large species is possibly represented outside of this state by a few fossil teeth found in Indiana and Texas. From the asphalt beds more than fifty good skulls with parts of many other skeletons have been obtained. Bones of the large wolf are much more common than those of the smaller one, and it is probably fair to assume that it was a more abundant animal than the coyote in this region at the time the beds were accumulating. Judging from the great number of remains found it certainly must have been very common in this region. The great wolf differs from all of our existing species in its larger and heavier skull and jaws, and in its massive teeth. Judging from the form of its skeleton it was less agile, and not so swift-footed as the coyotes.

The Sabre-tooth Tiger

Next to the large wolves the carnivorous animals most frequently discovered are the sabre-tooth tigers, of which thus far excellent material of over twenty individuals has been found. Though fossil cats of this group are known from nearly all parts of the world, and the type has been in existence for many geological periods, there has never before been found such a remarkable accumulation of their remains as occurs here. In all parts of the beds where collections have been made their bones are represented. At one locality eighteen complete skulls, and at least one complete skeleton, were found within an area of less than two square yards.

Use of the Tusks

The sabre-tooths belong in a large division of the cat family in which the upper canine teeth or tusks tended to be extraordinarily elongated. The representative in the asphalt beds was about the size of a large African lion, and was one of the most extraordinarily specialized members of the whole cat family. Its upper canine teeth were developed as long, thin sabres with finely toothed or serrated cutting edges. They were so much elongated that they must have protruded below the lower jaw when the mouth was closed. Though they are most beautiful cutting weapons, it has been supposed by some that they were almost useless, because the mouth could not have been opened wide enough to bite easily with them in the ordinary way. In the apparent absence of a normal function, all manner of peculiar uses have been suggested, varying from aids in climbing trees to a use as anchors for holding fast to floating ice. Some years ago Dr. W. D. Matthew of the

American Museum showed quite convincingly that the structure of the skull indicated extraordinary strength and peculiarly advantageous situation of the muscles used in jerking the head downward; suggesting that the sabres might have been used with a downward stab. It was also shown that the structure of the lower jaw is such that it may have been dropped, or the mouth opened so far as to remove the jaw from the field of operations while the sabres were being used.

Extraordinarily Powerful Claws

In killing their prey the large felines of the present day generally spring for the throat, and having once fairly fastened themselves upon their victim, they hold on with great tenacity. In the case of the specialized sabre-tooth cats, the necessity of releasing the hold with the mouth and stabbing or slashing repeatedly with the knife-like canines would make the animal's position insecure; and it is not surprising to find this need for a stronger hold with the feet met by the development of extraordinarily powerful claws, which greatly exceed those of the African lion in both relative and absolute size.

Altogether, the destructive apparatus of the sabre-tooth tiger was one of the most deadly combinations that has been found in any flesh-eating animal, but like the delicate mechanism of a high power gun there seem also to have been great possibilities for becoming disabled; and if the long, thin sabres were once broken the sabre-tooth would be less effective than the other large cats. It is interesting to note that in a large number of specimens found there is evidence of fracture or loss of one or both sabres long before the death of the animal, so that the extreme specialization of this creature may have led to a stage at which accidents occurred so commonly as ultimately to destroy the type.

The Giant Ground-sloth

Another animal found frequently in the asphalt beds is the ground-sloth, a peculiar creature, related on the one side to the living South American sloths, and on the other side to the armadillos. No representative of the group is known among the existing animals of the world, and most of the extinct representatives known are from South America, where they were abundant for a long period. The ground-sloths were much larger than their living cousins, some of them attaining the size of a large ox, and certain South American forms were even larger. They were powerfully but clumsily built, and the designation sloth is evidently not entirely inappropriate for them. The teeth of the ground-sloth indicate that they fed upon plants. Their feet were provided with very large and powerful claws, which were evidently used in digging or scratching for food.

The ground-sloth remains found in the asphalt consist of many parts of the skeleton, including feet with the enormous digging claws, and skulls with the teeth. In some instances nearly the whole of the skeleton has evidently been buried in the asphalt, but a portion of it has afterward been exposed and destroyed.

Bony Layer in the Sloth Skin

Some of the most interesting remains of the ground-sloths are those which indicate the nature of the skin. Excepting in cases where the dermal or skin covering of an animal is of some very resistant material, such as bone, it is rarely preserved in the fossil state. Feathers and hair are therefore great rarities as fossils, and even horny plates or scales are very seldom preserved. As the ground-sloth remains have until recently given no evidence of the presence of a bony covering or carapace similar to that of the armadillo and its relatives, it has been supposed by many to have been covered with coarse hair like that of the recent sloths. In a small number of cases, however, there have been found associated with some of these fossil sloths a few very small superficial bones somewhat like those covering the armadillo, and these have been considered as possibly present on a limited portion of the body.

Like an Armadillo

Very little was actually known concerning the nature of the covering of the ground-sloth until about eleven years ago, when Dr. F. P. Moreno of the Chile Argentine Boundary Commission found, at Last Hope Inlet, in Patagonia, a peculiar piece of dried skin which largely solved the mystery. The outer side of the skin was covered with long coarse hair, while the inner side contained embedded in it a great many small pebble-like bones. The skin was found to have come from a deposit in the floor of a cave in this region, and other skin fragments with many parts of skeletons were afterward recovered from this place. An exhaustive study of the skin and bones by Dr. A. Smith Woodward of the British Museum showed that they had come from a ground-sloth. These remarkable specimens demonstrated that this sloth had on the outside of his skin a coat of hair like that of a true sloth, but that inside there was a partial bony armor somewhat like that of its cousin, the armadillo.

Man Contemporary of the Ground-sloth

The skin and the bones of the ground-sloth found in the cave show peculiar cuts, which can hardly be interpreted as produced in any other way than through the agency of man. This and other evidence obtained from the cave indicates that man was a contemporary of the ground-sloth. This evidence naturally led some to suppose that the animal was still living. In support of this view Indian legends were reported to the effect that a strange, huge, hairy animal lived in the region of the southern Cordilleras. In 1890 an expedition was sent through Patagonia to search for the living animal but without success, as might presumably have been predicted, since many of the bones of other animals associated with the ground-sloth in the cave represented extinct types. On the other hand, how the skin came to be so well preserved after an evident lapse of a very long time has not yet been fully explained.

Hopes Realized

During one of the first examinations of the bones from the Los Angeles asphalt deposits several small pebble-like bones were found which showed similarity to no known bony structure excepting the ossicles from the ground-sloth skin of Patagonia. This suggested the possibility that, as ground-sloth limb-bones and teeth were known in these beds, a considerable part of a skeleton might be found mired in the asphalt, with the indestructible bony portions of the skin still in place around it. During the second visit to the beds a deliberate search was made for a ground-sloth skeleton surrounded by the bony layer of the skin. In a hunt of an hour or so two lots of ground-sloth bones were located in a cut in the asphalt, and curving over them in each case was a layer of the small pebble-bones, just as it had been surmised that they might be found. These pieces when worked out in the laboratory show the pebble-bone layer not greatly disturbed, indicating that at least some portions of the animal had been early and completely covered over, and preserved against the action of the atmosphere. As yet no remains of a hairy outer coat have been found with these specimens, as hair is possibly too delicate to be preserved under the conditions obtaining here.

In Dr. Matthew's observations on the sabre-tooth tigers already mentioned, the suggestion was made that possibly the existence of elongated sabres in the great cats was to be correlated with the presence of large animals with thick necks, through which the tiger could not penetrate with the ordinary kind of canine teeth. The ground-sloth was apparently just such an animal, and clumsy as it was, it must have offered considerable resistance to carnivorous animals through its very bulk, so that a special killing apparatus was needed if it was to be hunted successfully. Its presence in association with skeletons of sabre-tooth cats, as occurs frequently in the asphalt, may therefore be due to the attraction of the big cats by mired ground-sloths.

Bison, Camels and Mammoth

Of the hoofed, herbiverous animals found in the asphalt beds, extinct species of horse and bison are the most common. Occurring less frequently are camels, deer, goats, a small and previously unknown deer-like animal, and the mammoth. Nearly all of the horses are young animals, and the bison are usually represented by calves. The horses belong to a species much like the modern type. The bison were heavy-horned species, somewhat larger than the existing American buffalo. Of the mammoth only portions of the tusks and limb-bones have thus far been found.

The bones of the birds are very common and are mingled with those of the other animals, particularly the carnivora. Of beetles, the wing covers and even the whole bodies are found, and with them are occasional remains of centipedes, and the bones of various rodents.

From the occurrence of so many peculiar intermingled animal remains, in which the proportion of carnivorous animals and of young ones is relatively large, it may be judged that the accumulation of bones found here has taken place under conditions materially different from those under which bone deposits have commonly formed. In most instances fossil bone beds represent the natural collection of remains by stream wash, or simply the dust-covered skeletons accumulating on open plains. In such cases most classes of animals are represented among the skeletons in somewhere near the proportion which they bore to the other forms of life. In the asphalt beds the percentage of carnivora and of young animals appears much larger than it could have been in any normally balanced fauna, and there must have been some extraordinary reason for the presence of these classes in such relative abundance.

The asphalt deposits as a whole have evidently formed from the slow accumulation of bituminous material around tar springs. Springs of this kind, such as are in existence at the present time in this region and elsewhere, generally send out a great deal of water with the bituminous material, the tar accumulating on the floor and around the margins of ponds of water. After a time the tar accumulates in such a quantity that it may of itself form a large pool. With evaporation of the more volatile materials the bitumen gradually hardens, but in warm weather the surface is always soft and sticky, and when the mass has accumulated to a sufficient extent it may flow and spread for a considerable distance.

In all stages of the accumulation of asphalt the gummy surface presented to the atmosphere acts as a trap for unwary animals. Where pools of water are present, water birds of all kinds are caught in the soft tar about the margins of the ponds. When once the wing feathers are smeared over the birds are helpless, and in attempting to wade out to dry land they are hopelessly mired. Land birds and mammals in smaller numbers are caught in attempting to reach the water, while insects and other tiny creatures are snared.

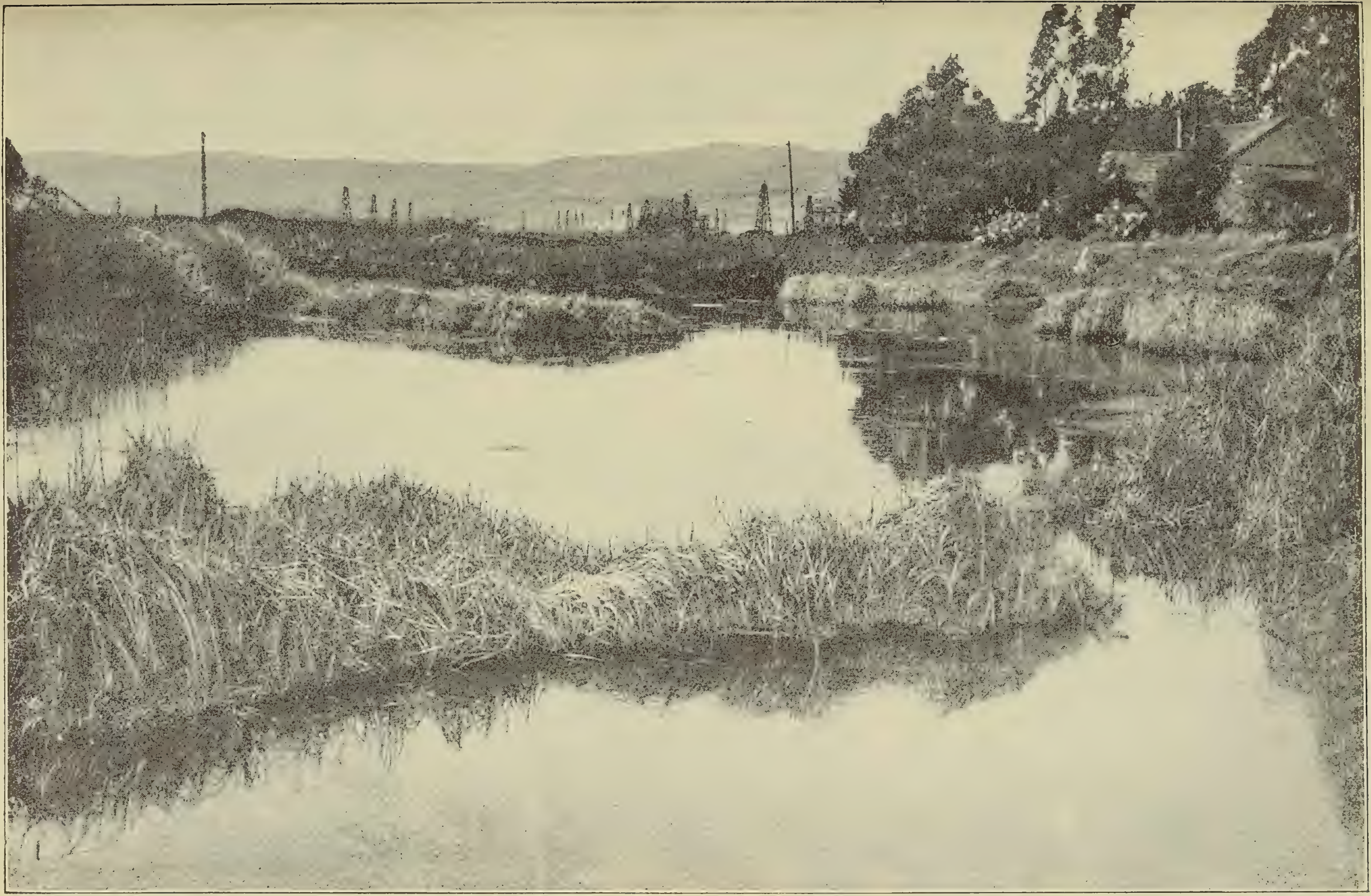
Where asphalt has accumulated so as to form a pitchy lake, it presents a surface which looks very much like water, at least in a dim light. In one large pond of this sort known to the writer, many birds have come in and settled down as if upon water. Many owls have also been trapped in the same pool, as they have attempted to catch mired birds or mice.

Even the nearly solid asphalt masses, when they are heated up by the sun so as to flow slightly, serve as traps, particularly to the large mammals which attempt to walk upon them. In Ventura county, California, where there are several areas of this sort, colts and cattle are frequently caught, and on one range it was necessary, some years ago, to ride over the ground every day in summer, to pull out colts caught in the tar. In this region mountain lions were common and may have stampeded some of the young animals, causing them to run into places where they would not otherwise have gone.

The fauna of the asphalt beds of Los Angeles so far as most of the types of animals are concerned, corresponds very well with what is found in the tar deposits at the present day. Of the birds a large percentage are water forms, and of the larger herbiverous mammals nearly all are young animals, like the colts and calves caught in recent times. The large number of carnivora present also corresponds with what is noticed around recent asphalt pools, where unwary cats and dogs are only too frequently lost in attempting to reach struggling birds or small mammals that have previously been caught in the tar.

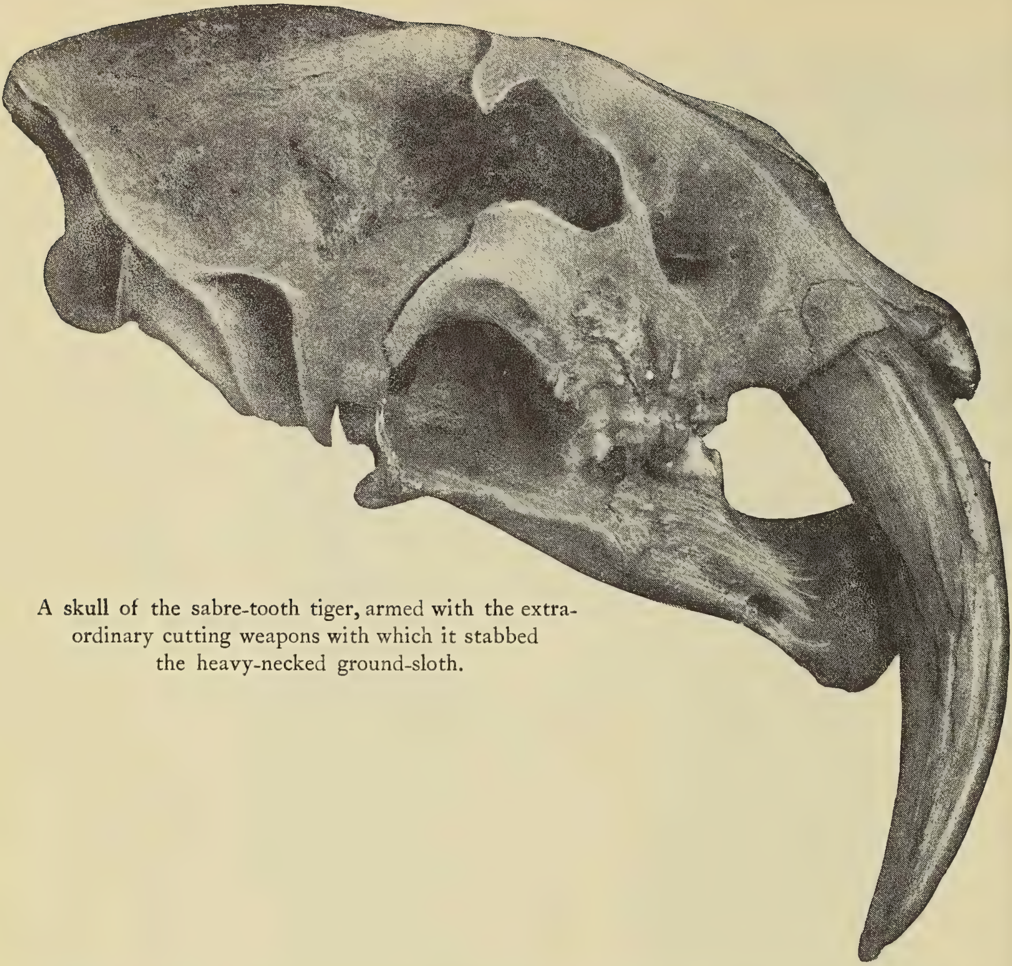
There seems, then, to be every reason to believe that the Los Angeles asphalt deposit with its great freight of bones has been formed in a past geological period, much as the deposits are being made about tar springs at the present day. The peculiar ducks and pelicans and condors, the young camels, bison, horses, and deer, with the mammoth and the ground-sloth, have sunk in the pitch, and in their struggles have enticed the wolves, bears and the sabre-tooth cats. Sometimes a single struggling animal may have attracted several wolves or tigers, and around its body a combat was carried on which ended in both the victor and the vanquished being swallowed in the tar. In other cases the presence of several puppies or kittens together with an adult of middle age leads one to suspect that a young litter has broken loose to fling itself upon some mired bird or mammal and has been trapped together with the mother which came to their aid.

The accumulation of the asphalt beds has probably gone on slowly for a long period. Sometimes it ceased entirely. At times conditions were such that few if any animals were trapped. At other periods a great variety of creatures was caught in such numbers that their bones were matted together in thick beds, which we now recognize as strata in an ancient geological formation.

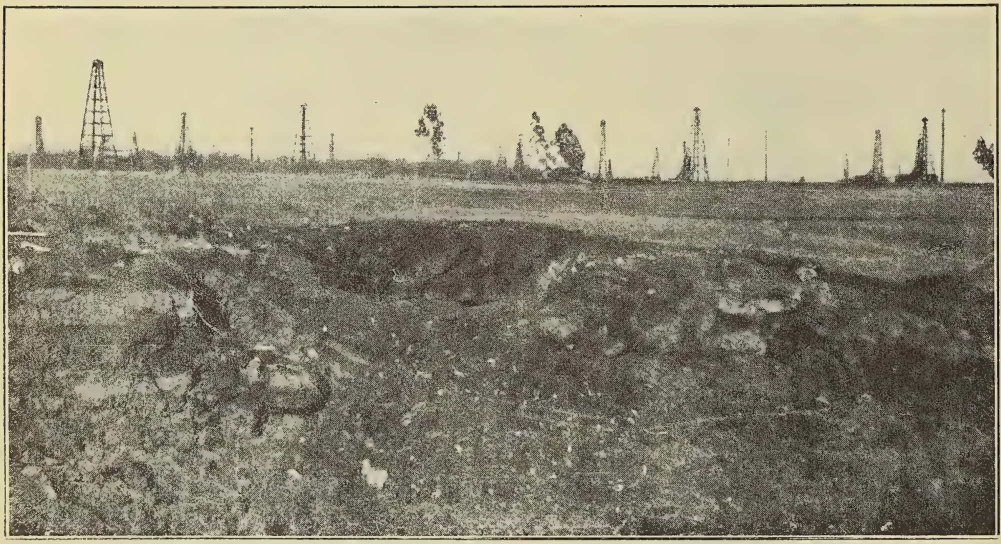


The death trap of the ages, near Los Angeles, California. Upon the innocent-looking surface of this lake, in the midst of the asphalt beds, settle unsuspecting waterfowl. Seepages of oil and asphalt constantly ooze from the banks and large bubbles of gas break upon the surface of the water.

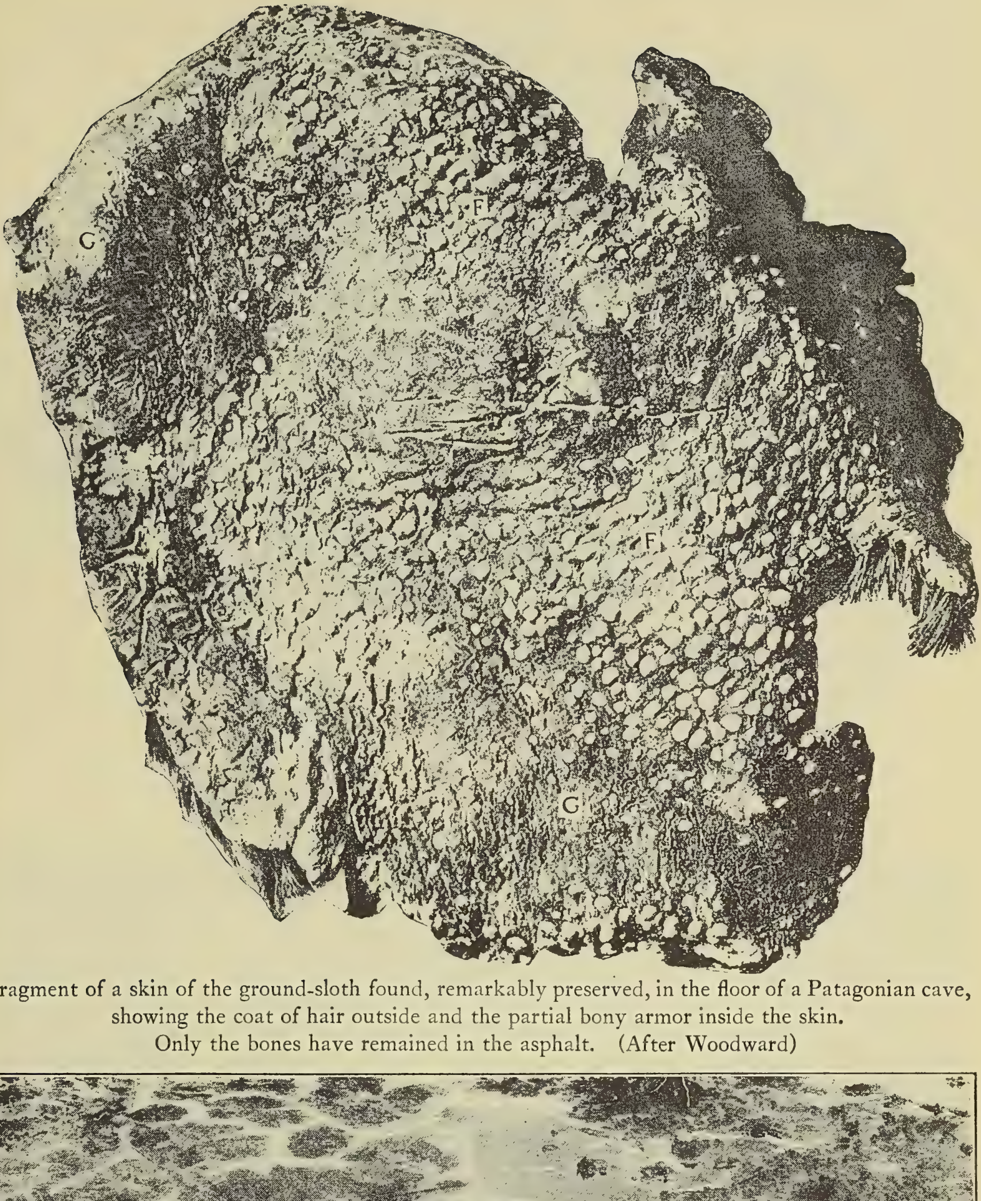
In the treacherous margins of this pool, birds and mammals and insects are constantly being trapped today as in the untold yesterdays.



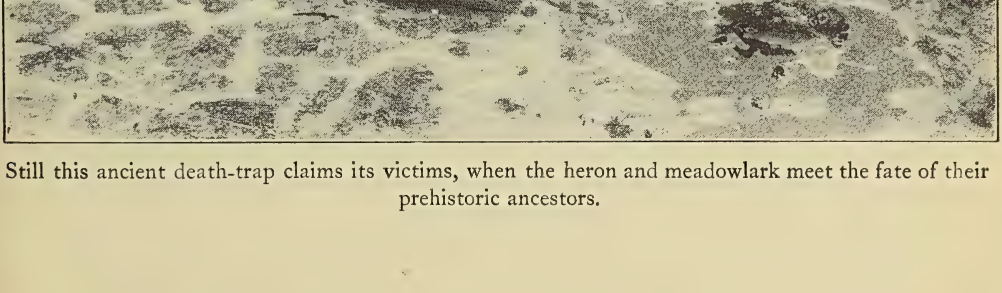
A skull of the sabre-tooth tiger, armed with the extraordinary cutting weapons with which it stabbed the heavy-necked ground-sloth.



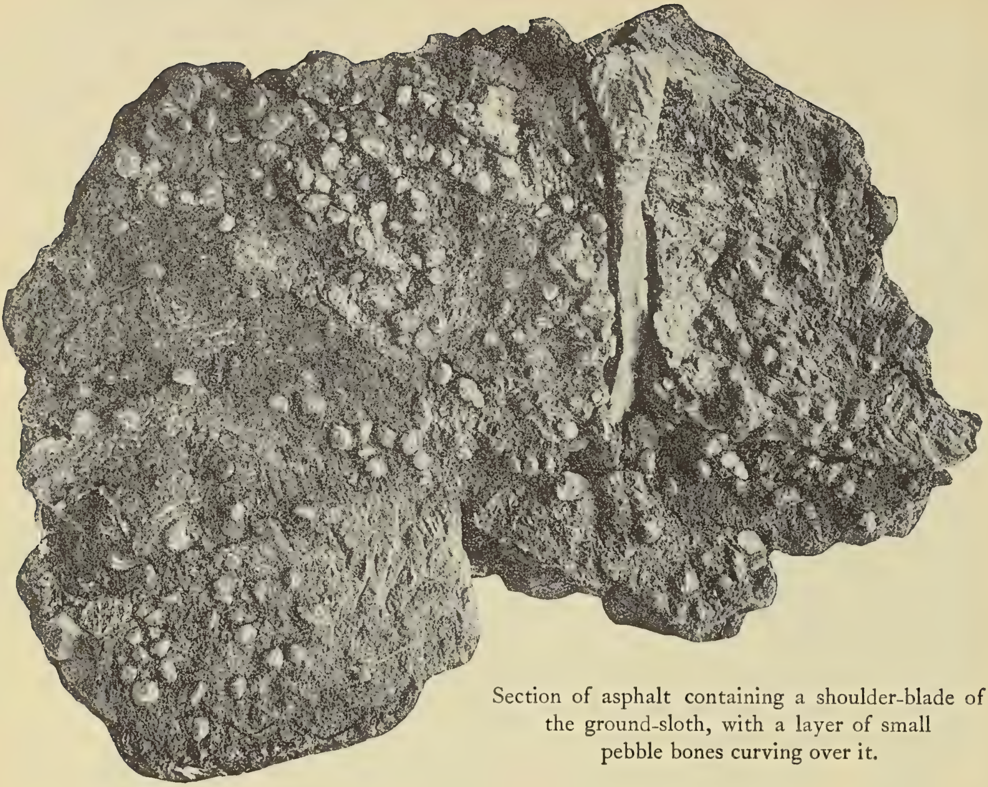
Looking north from the asphalt beds, showing the general character of the country and the derricks of near-by oil wells.



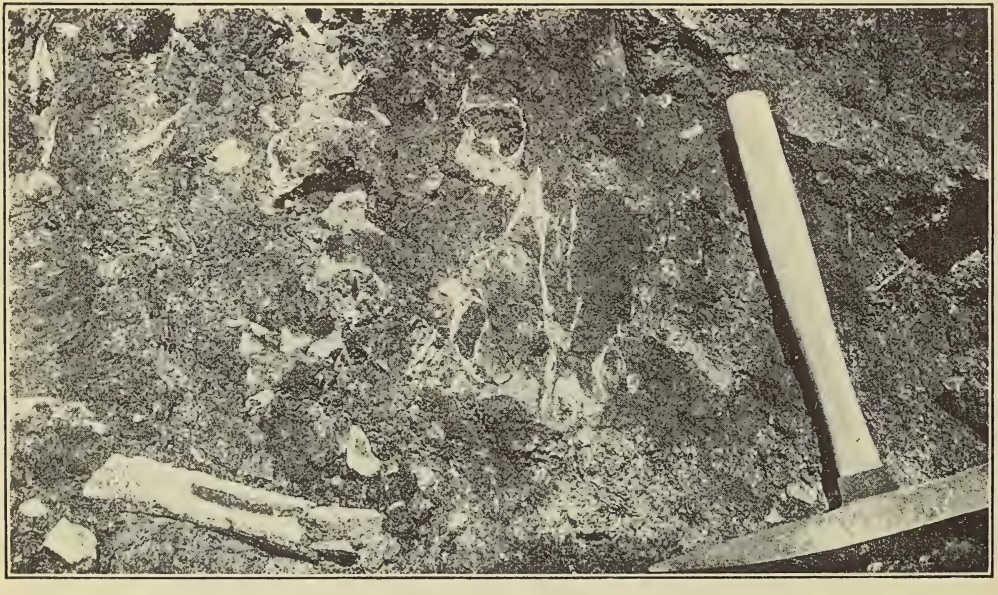
Fragment of a skin of the ground-sloth found, remarkably preserved, in the floor of a Patagonian cave, showing the coat of hair outside and the partial bony armor inside the skin. Only the bones have remained in the asphalt. (After Woodward)



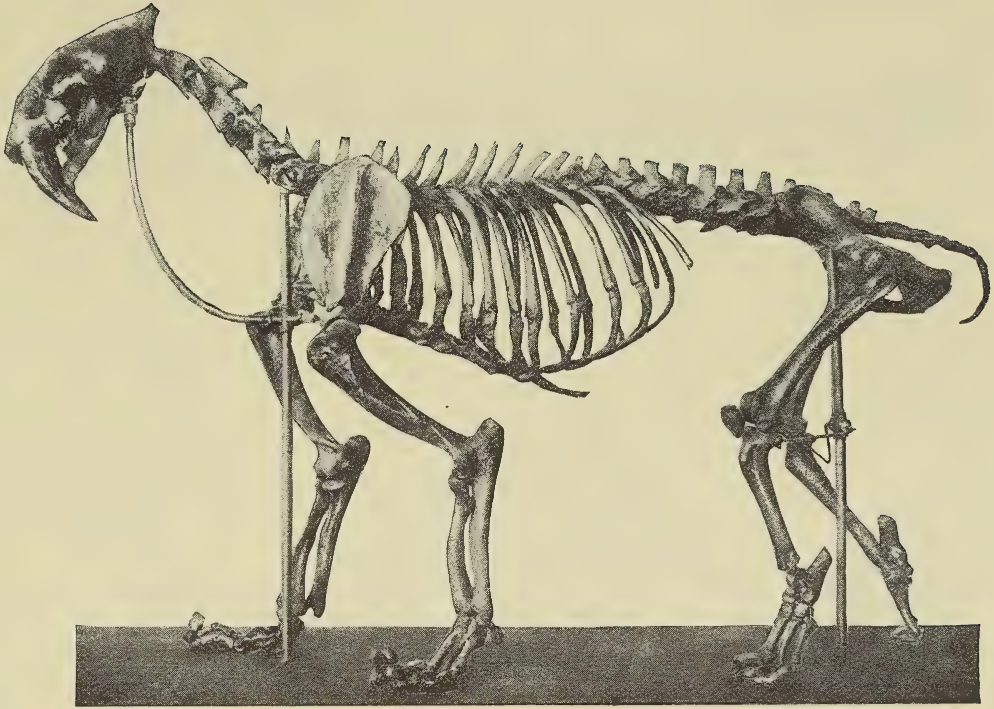
Still this ancient death-trap claims its victims, when the heron and meadowlark meet the fate of their prehistoric ancestors.



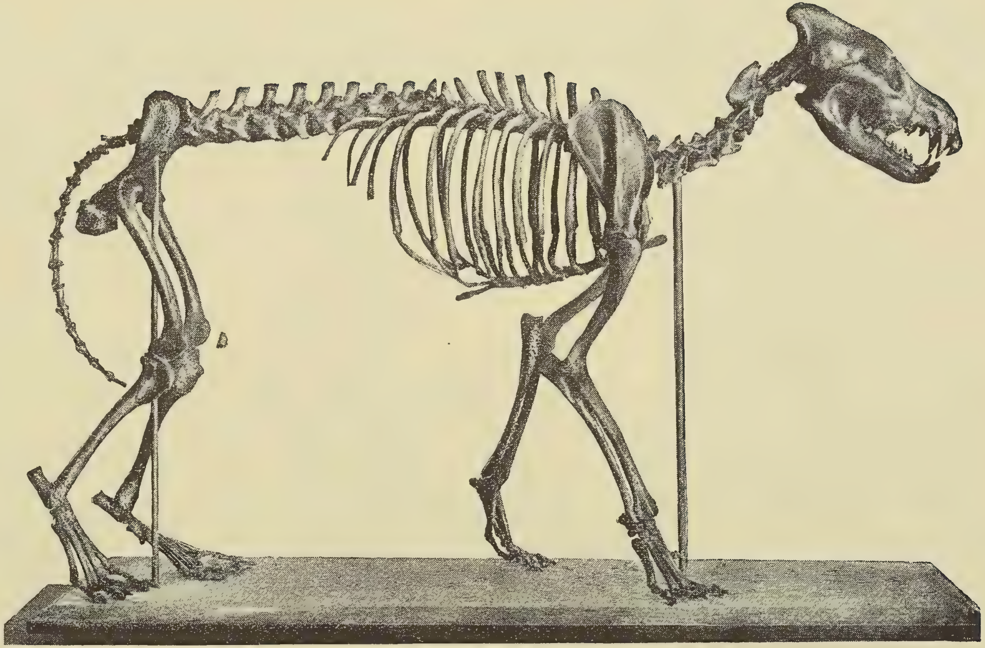
Section of asphalt containing a shoulder-blade of the ground-sloth, with a layer of small pebble bones curving over it.



A section of fossil beds showing white bones in the solid matrix of asphalt. Here is written, in black and white, fascinating records of prehistoric life, pages now opened to the eager eyes of the scientific world.



Skeleton of the giant cat, showing the sabre-like canine teeth. The short tail resembles that of the American wildcat.



A complete skeleton of the great wolf, once a common animal in California.

A DEATH-TRAP WHICH ANTEDATES ADAM AND EVE

THE DISCOVERY OF A CALIFORNIAN TAR-SWAMP THAT HOLDS THE BONES OF EXTINCT MONSTERS

The western portion of the North-American continent has been so generally recognized as one of the most interesting regions of the world for the study of the life of past geological periods, and has therefore been so assiduously explored for many years by geologists and palæontologists, that the discovery of a new field for investigations of this nature almost within the limits of a large city is distinctly surprising. Yet this has recently been made in the location of a great accumulation of remarkably preserved remains of extinct animals in deposits around prehistoric tar or asphalt pools at Rancho La Brea, near Los Angeles.

For nearly half a century the great asphalt deposits stretching through the western part of Los Angeles have been known by geologists to contain skeletons of large animals in abundance, but with a single exception no investigator seems to have had a suspicion as to the actual nature of the remains. As all kinds of wild and domestic animals were known to be mired in the tar springs, it was perhaps natural that bones found in the hardened asphalt should have been considered of quite recent origin. Even Whitney, the State geologist, in his report published in 1865, referring to these beds, speaks of "a very large amount of hardened asphaltum mixed with sand and the bones of cattle and birds which have become entangled in it."

A very brief note on the fossil remains from the asphalt beds, published as an abstract from a letter by William Denton in 1875, seems entirely to have escaped attention. Denton mentioned having received a canine of the large sabre-tooth tiger from Major Hancock, the owner of the ranch, who was presumably the first person to take particular notice of the fossils in the asphalt.

So far as a somewhat extended inquiry can determine, excepting the observations of Denton, Mr. W. W. Orcutt, of Los Angeles, was

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the first geologist to consider the bones at Rancho La Brea as those of prehistoric animals. Mr. F. M. Anderson, of Berkeley, to whom Mr. Orcutt exhibited his collection, recognized a number of the specimens as resembling extinct carnivora then being investigated by the writer, and very kindly brought to him a small package of bones and teeth.

Mrs. Ida Hancock, the owner of the property, generously permitted the University of California to take up excavation work, which has been prosecuted as much of the time as possible since the discovery.

The fossil beds at Rancho La Brea lie immediately to the west of Los Angeles, in an almost level area bordered by the Santa Monica range to the north. Asphalt is not exposed everywhere, but in a surprisingly large number of places it forms the surface of the ground, or is shown in heavy layers in the banks of streams or pools. In other places tar frequently oozes up through small craters or pipes, and spreads over the surface of the ground. The area in which these exposures occur is quite irregular, but probably occupies altogether a considerable part of a square mile.

The formation in which the asphalt beds occur consists of irregular beds of sand, gravel, clay, and asphalt. It seems to have been built up in a fairly level region, out of the wash of adjacent highlands mixed with tar oozing up from below. The geological structure of the formations underlying this alluvial accumulation indicates the presence of a fold in the older strata, from the broken summit of which oil and tar have been oozing for a very long time. As the strata piled up, tar springs impregnated the surrounding sand and clay beds, or formed layers of nearly pure asphalt.

The fossil remains are found in a practically unaltered state in the asphalt layers, and to some extent in the tar-impregnated sand and clay strata. The bone deposits are more or less irregular, and are often only small pockets, such as one would expect to find in the most treacherous portion of a tar seep or pool. Bones are in places so numerous as to form a tangled, matted mass, from which it is difficult to extract one specimen without injuring others. The number of individuals is often very large, and of some forms, as of the great sabre-tooth tigers, probably more specimens have already been recovered here than were known previously in the combined museums of the world.

The remains of mammals and birds determined thus far in the university collections include the following forms: Great Wolf (extinct species); coyote (extinct species); timber wolf (extinct variety); gray fox; wildcat (two forms, one possibly extinct); great American lion (extinct); sabre-tooth tiger (extinct); badger; skunk; weasel; bison (extinct species); small deer (extinct species); camel (extinct species); horse (extinct species); mastodon (extinct); elephant (extinct species); ground sloth (extinct); ground-squirrel; rabbit (two species); kangaroo rat; field-mice; gopher; California condor; golden eagle; teratornis (gigantic extinct bird); short-eared owl; burrowing owl; California peacock (extinct); turkey-buzzard; red-tailed hawk; long-eared owl; Canada goose; California black vulture (extinct); marsh hawk; barn owl; great horned owl; great blue heron; American raven.

Of the recent discoveries made in the asphalt work, one of the most interesting is the finding of a gigantic lion, representing the group of true cats as contrasted with the sabre-tooth cats which have been found here so abundantly. Although fragments of the skeleton had been known for some time, the first recognizable specimen was obtained in December, 1908, by Dr. William Bebb, of Los Angeles. The skull found by Dr. Bebb resembles that of the modern African lion in its general characters, but is larger than in any other member of the cat group, recent or fossil, of which any record has been obtained by the writer. The species seems to be the same as that represented by a large jaw fragment obtained in 1836 in the vicinity of Natchez, Mississippi. This animal was given the name American lion by Professor Leidy, who first described it. It probably had a wide range over North America in the last geological period.

It is interesting to note the presence in the same asphalt beds of the great American lion along with the sabre-tooth tiger, the two representing the highest stages of development of the cat group, and being at the same time two of the most formidable carnivorous creatures that have existed. They represent two quite distinct divisions of the cat family, which developed concurrently through many geological periods, but reached their highest stage of efficiency in these two types. The true cats, represented by the lion, although very ancient, have been less important in past geological periods than the sabre-tooths. They are, apparently, a production of the Old World, having come into America in comparatively late geological time. The sabre-tooth group, on the other hand, has flourished for many periods and was represented in North America by numerous species and individuals.

These two great groups of animals, represented by their most formidable types, existed together in the environs of the Brea pools. What battles were waged between them we can only conjecture, but we may feel certain that encounters were not to be avoided. The sabre-tooths outnumbered the lions at least five to one, judging from the number of specimens found. The combats were, however, not ordinarily between groups, but between individuals. The style of attack of the two animals must have been fundamentally different. Both animals slashed and tore with their claws. The lion, with its powerful jaws and monstrous biting muscles, throttled its prey, shaking and twisting it as a modern cat deals with a rat or rabbit. The sabre-tooth slashed and stabbed with its knife-like teeth, sometimes incapacitating its adversary with a single blow. In some cases while lifting its head to strike it gave an opening for the lion to attack its throat and the battle was quickly ended. At other times a blow from the lion's paw may have broken its long, thin sabres, and rendered it a comparatively inefficient adversary.

However we may calculate the chances of these battles, later history shows us the sabre-tooth group disappearing entirely, while the true cat group is now numerously represented over a great portion of the earth's surface.

Some of the most interesting work done on the Brea fauna in the last year is that of Mr. L. H. Miller, who has been investigating the fossil birds. A gigantic bird entirely different from any form heretofore known, living or fossil, is one of his discoveries. It has recently been described by Miller under the name *Teratornis*. The skull is that of a carnivorous bird, and larger than either the condor's or the eagle's. A number of enormous wing and foot bones have been found which presumably belong to *Teratornis*, but the degree to which its limbs were developed for flight or for running has not as yet been clearly determined.

An extinct peacock from the asphalt beds is another bird recently described by Mr. Miller. The living members of this family have been known only in the Indian region, although they are found fossil over a considerable part of the Old World, ranging into Europe. The discovery of specimens in the asphalt of Los Angeles indicates a very wide range of the family in the Quaternary period. It also suggests that in a comparatively late period a broad land connection must have existed between Asia and North America.

The manner of the accumulation of the skeletons in the tar is quite different from that in nearly all other fossil deposits. The fact that most of the bones are in the asphalt strata, while few or none are present in the beds of pure sand and clay, shows that tar has been the important factor in bringing together the mass of bones. Evidently the remains were not washed together by streams as in many deposits, otherwise they ought to be abundant in other strata also. All the evidence points toward the bone beds having been formed through the trapping of living animals in the sticky asphalt.

Illustrations of the way in which animals may be caught in tar or oil pools are only too common in California to-day, and many examples have been furnished by the existing tar seeps of Rancho La Brea itself. The writer is informed by the proprietor of this ranch that in many instances cattle, sheep, horses, chickens, turkeys, dogs, cats, and other animals have been so completely mired that they were freed only with the greatest difficulty. On the borders of nearly every seep there may usually be seen at the present time the carcass of some animal that has recently fallen a victim, and it is easy to imagine the result of long-continued operation of the tar pools.

An amusing illustration of the trapping power of asphalt was furnished some time ago by an occurrence reported from an interior California town. A number of workmen were engaged in covering a piece of road with asphalt, and had left their work only partially completed in the latter part of a warm afternoon. A drunken man passing a short time afterward fell by the roadside and remained there to take a nap. By chance he extended himself on some of the partly softened asphalt. Falling asleep quickly, he evidently lay for a long time without moving. During this period his body sank part way into the sticky mass. After the sun went down, and the atmosphere had cooled, the tar hardened somewhat, and by morning it was practically solid. When the man awoke he found it impossible to extricate himself. His cries attracted a number of persons, who attempted to free him. Unfortunately the whole side of his body and his head were firmly set in the asphalt, and it was very difficult to give him any assistance. With the aid of an axe and various other tools they finally succeeded in cutting and prying him out, but not without injuring him somewhat. He was taken to a hospital near by, where numerous attempts were made to separate the tar from his body. Only after shaving his head and scrubbing him with benzine was it possible to give him an aspect of respectability.

The remains present in the asphalt may be considered to represent nearly all the kinds of animals in the region at the time the beds were forming, but the percentage of specimens in some groups is so very unusual as to indicate that the number is by no means representative of the true proportion of the individuals of these kinds to the whole fauna. In other words, the peculiar conditions under which the deposits have formed, and the peculiar manner in which the animals have been buried, give us an entirely different kind of a representation from that which we ordinarily find in fossil-bearing formations.

The most common animals represented are carnivorous, or flesh-eating types of mammals, birds, and insects. The statistics which we have thus far been able to obtain show that more than half of the total number of skeletons recovered are those of carnivorous creatures. Such a proportion as this could, of course, not exist under normal conditions in any fauna. The carnivora are dependent for their food upon the herbivorous animals, and a natural balance of life must give us many herbivores to offset each carnivore; otherwise the carnivores would soon eat up the herbivores and then die of starvation.

The relatively great number of carnivorous animals, which is the most striking feature of the Rancho La Brea fauna, is undoubtedly to be accounted for in a large part through the luring of carnivores into the asphalt by any creatures which may have been entrapped in the tar. Such live bait, by its struggles and cries, would undoubtedly attract cats or wolves, and not improbably several carnivores might be led into the asphalt by the same bird, bison, or colt. It is easy to imagine an animal caught in the black ooze surrounded by a group of tar-besmeared wolves, each trying to make a meal of the unfortunate creature that drew him in; at the same time fighting with the others, and attempting to extricate himself from the tar. As a result many of the animals concerned would probably be completely exhausted and die in the asphalt. Such skeletons would in most instances be preserved intact for some time. Parts of the body might be exposed, and would decay and entirely disappear. Probably in most cases the entire skeleton would finally be covered over.

As has been shown by Mr. Miller, what is true of the mammals is true also of the birds, nearly all of which represent such groups as the eagles and vultures, which have been attracted by dead or dying animals, and were thus entrapped. In turn the struggling vulture attracted the wolf, and the wolf attracted the lion, thus baiting a trap which was set continuously, and an accumulation of bones grew rapidly from year to year.

Among the herbivores it is noticeable that a very large proportion of the total number of individuals consists of young animals instead of the adults which normally make up the largest part of any group. In fact, considerable difficulty has been experienced in the study of some forms, as, for instance, of the horses, in obtaining specimens old enough to show us the permanent teeth. Nearly all of the individuals in the university collections are colts with milk-teeth only.

Fortunately there is plenty of evidence obtainable around asphalt deposits in California at the present time showing this to be explained by the inexperience and excitability of young animals, which are stampeded by wolves or lions, or from simple lack of experience, and run into situations that older animals would avoid. With less intelligent handling of their limbs, and less strength, the young are unable to extricate themselves, and become a prey to the black pool.

Among both the herbivorous and carnivorous animals there is also an unusually high percentage of diseased and maimed individuals. This is true not only of the mammals, but also of the birds.

In the sabre-tooth cats the sabres are frequently broken off and the fractured ends are polished down on the parts which would be used in biting after the break occurred. In some cases the amount of wear shown in a broken tooth is almost comparable to that on other teeth which have not been fractured, showing that the accident occurred in early adult life. In some animals one sabre is broken and the other entire, and in others both sabres have been broken.

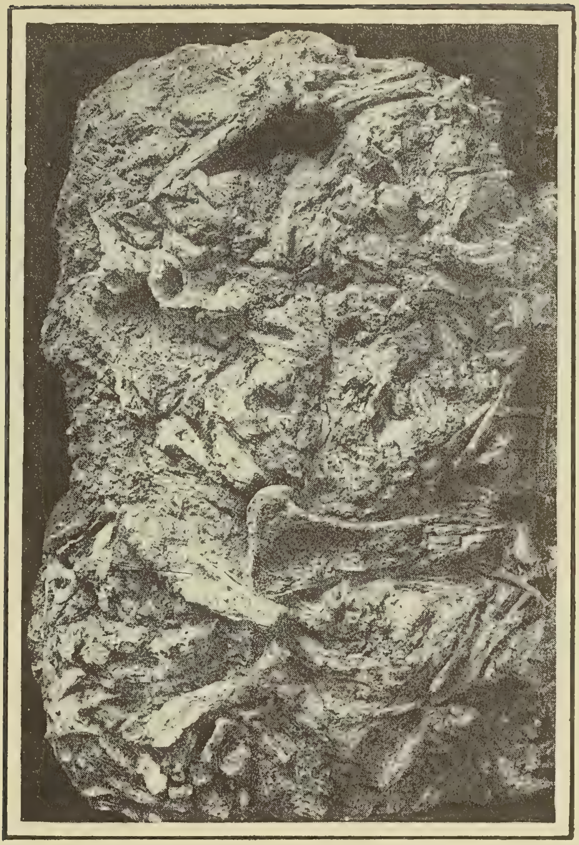
Evidence of tooth-wounds obtained in combat with other animals is seen in the jaws of wolves and sabre-tooths. In a number of cases the wounds have partly healed and the animal evidently lived for a long time after having been injured.

In several cases the skulls of wolves show cuts which have the form that would be given if they had been made by canines of the sabre-tooth, and there seems reason to suspect that the wolves were attacked after they had been entrapped and were struggling in the tar.

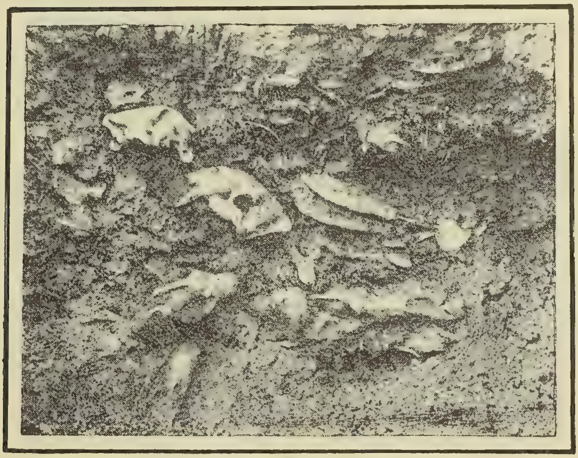
Growths of diseased bone are seen not infrequently in the large wolves, where they are found in practically all parts of the skeleton and may suggest a decadent condition of the species in general. The most remarkable case observed is that of the hind foot of a wolf, in which the four bones supporting the toes have grown together, and their upper ends are covered with a voluminous pathological bone growth. Another interesting case cited by Mr. Miller is that of an eagle in which the middle of the shank became so diseased that the end of the foot was lost entirely.

At the time the beds now exposed at Rancho La Brea were forming, the country was evidently a very nearly level plain, much as it is at the present day. Judging from the rarity of coarse gravel beds, and the presence of thick strata of clay in some exposures, there was no large amount of wash from the hills at this locality and the ground was probably marshy in some places. The amount of asphalt oozing out at that time seems to have been larger than it is to-day. Water probably came out with the tar, and pools of water and tar, both combined and separate, were characteristic features of the landscape. In all of the deposits that have been examined thus far there is a great deal of buried wood—tree trunks, branches, and sometimes masses of small branches, twigs, and leaves—so that the plain must have been at least partially covered with trees.

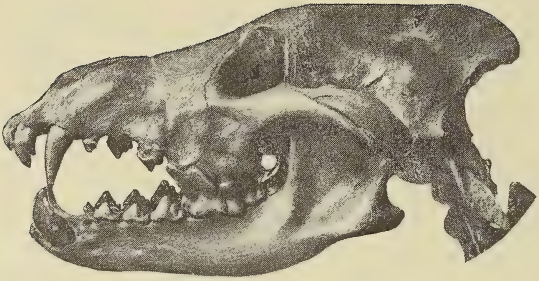
A region of this nature, with water, moist ground partly grassed over, and at least a portion of the country wooded, should be a natural gathering-place for many kinds of herbivorous animals, and therefore of the carnivorous types which preyed upon them. The rushes and other rank vegetation about the pools, with groves and patches of brush, while affording a certain degree of protection for the most timid herbivorous animals, also afforded an excellent field for the stalking operations of the hunting carnivora; so that both groups were probably well represented. The great quantity of remains in the asphalt is in itself an evidence that unusual attractions existed at this locality. Only on the supposition that the region was more than ordinarily alluring, and that animals were abundant in the surrounding country, can we account for the very large number of creatures that were trapped.



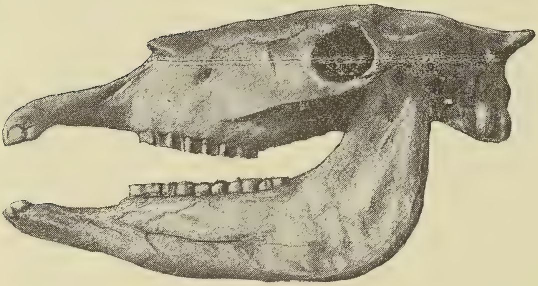
How the bones occur in the asphalt



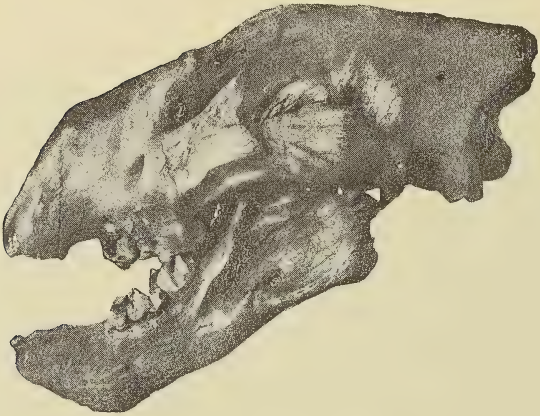
Some fragments of bones still unremoved



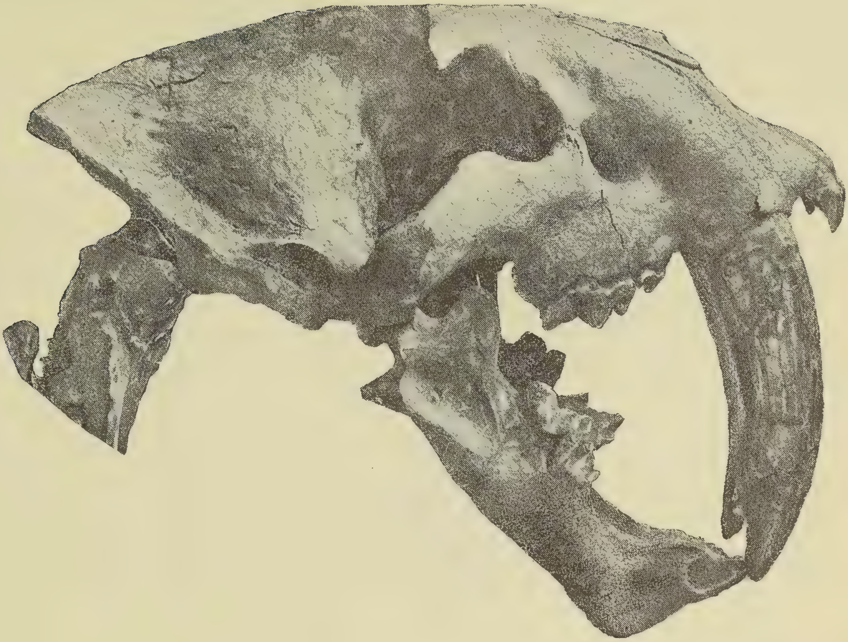
The skull of the great extinct wolf



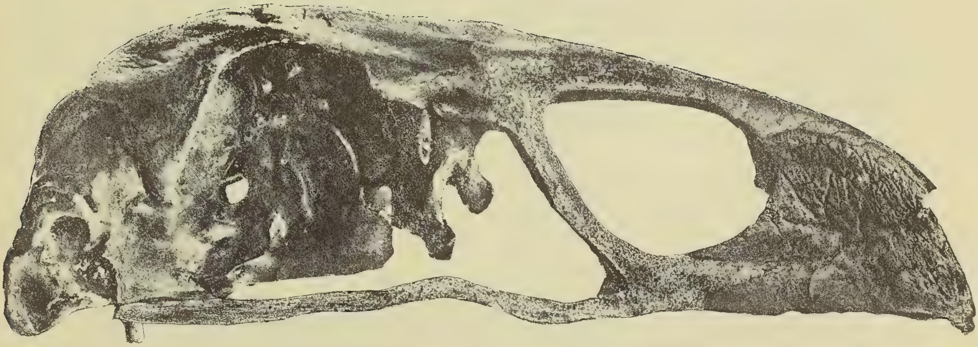
The skull of a colt of extinct species



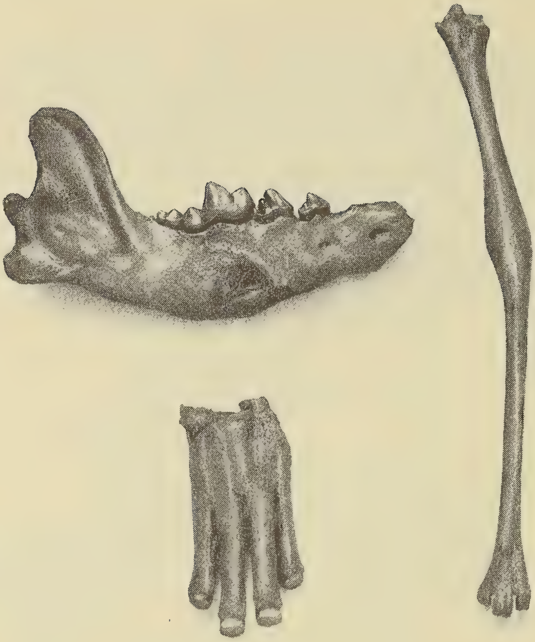
The skull of the great American lion



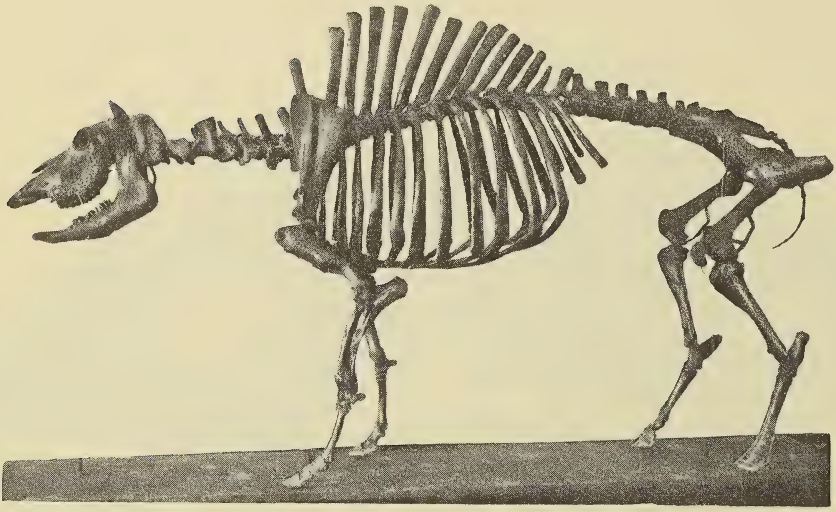
Smilodon californicus, the terrific sabre-toothed tiger



The skull of the teratornis, a gigantic extinct bird, probably larger than the condor



The shank of a crane, a wolf's foot, and a wolf's jaw, broken during life, and badly healed



The skeleton of the primeval bison

THE TRUE STORY OF THE CALAVERAS SKULL

In the study of prehistoric America, one of the most important questions asked is: "When did the human race first colonize this continent?" There are some who maintain that man had occupied America before the beginning of the present geological period—others believe him to be a comparatively recent arrival. The discussion of this question has been closely and carefully contested, and it has fallen to the lot of practically all human remains, reputed to represent American men of geologically ancient date, to become veritable bones of contention.

Of the various relics discovered up to the present time, probably none has become better known than the much-discussed Calaveras skull; certainly no other has been the occasion of such remarkably contradictory statements as have been recorded in reference to this specimen.

Attention was generally attracted to the Calaveras skull by a short notice of its discovery presented before a meeting of the California Academy of Sciences in San Francisco in July, 1866, by Professor J. D. Whitney, then State Geologist of California. According to the story as given by Whitney, the skull had been found by Mr. Mattison of Angels, up in the Bret Harte country of the Sierra, at a depth of one hundred and thirty feet, in a shaft on Bald Mountain near the town. The formations overlying the gravel layer in which the specimen was said to have been found, and which must therefore have been formed since the skull was supposed to have been buried, consist of alternations of gravel beds and volcanic rocks deposited in a geological age several periods earlier than the present. The time of accumulation of these beds antedates the principal elevation of the Sierra Nevada range, and represents a period in which the animal and plant life of the earth differed entirely from that of the present day.

Contrary to what might have been expected, the form of the skull after it had been cleaned and prepared for study was not found to

Sunset, vol. 24, pp. 153–158, February 1910.

differ materially from that of modern California Indians. Man was thus apparently shown to have survived several total changes that have occurred in the life of the earth since the time of accumulation of the gravels, yet without having undergone any modification of his own physical structure, in contrast to the rule that the most highly organized creatures tend to change more rapidly than the simpler ones.

Whitney's account of his remarkable discovery did not meet with a general acceptance either by the public or by scientists. Scientific men on the one hand have felt that the occurrence of the skull in such ancient deposits indicated a mode of development of man on this continent entirely different from that known elsewhere; while the unscientific public hailed the story as a huge joke on the state geologist.

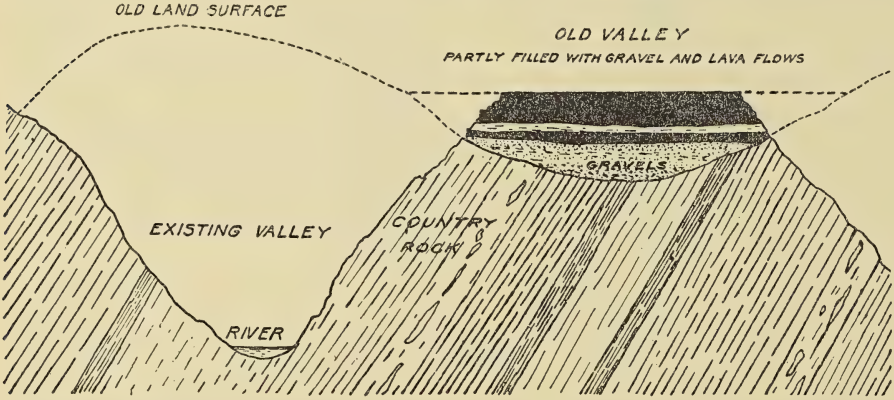


Diagram illustrating the great amount of erosion by rivers in the Sierra region since the gravels in the old river beds were covered by lava. Cañons cut to a depth of 2000 feet or more. The time required for this cañon cutting is very long. Human relics are supposed to have been found in the gravel under the lava.

The scientists who have investigated the history of the human race have accumulated a great volume of evidence indicating the close relation of physical man to an ancient group of large-brained animals including the existing apes and monkeys, and have traced the evolution or geological history of the human type in the Old World step by step from ape-like forms up to the present man. All that is known of the history of human beings in the Old World indicates that their evolution is governed by the same general laws that have controlled the evolution of other kinds of creatures.

The sudden appearance of highly developed man in America at the time the auriferous gravels were being deposited would be entirely contrary to the laws of evolution with which our history is in accord elsewhere. It would indicate on the one hand that man, the most progressive of all creatures, had remained in this region for several geological periods without having shown any physical advance or change, while the rest of the animal kingdom has steadily advanced in physical characters generally, and particularly in brain development. It would on the other hand be difficult to account for the presence of highly developed human beings in this region long before the appearance of the most primitive man-like forms elsewhere. In the epoch represented by the gravels in which the skull was supposed to be buried, this continent did not contain any ape-like or monkey-like creatures out of which man could have been formed by any known process of evolution. In the Old World the advancement of man has taken place in much the same way as the evolution of other animals, and we have every reason to suppose that creation has always been brought about by evolution, or by utilization of the most available materials in producing a new type.

Soon after Whitney's first publication relating to the discovery of the Calaveras skull, the public press seemed to discover that the finding of the skull deep in the shaft at Bald Hill had been carefully arranged by fun-loving residents of Angels, and that the eminent geologist had been sadly fooled. The religious papers particularly investigated the case and pronounced it a hoax originating with some mischievous miners who wished to play a joke on a man of an "anti-scriptural and geological turn of mind."

In championing the Calaveras man as geologically ancient, the severest blow to Whitney's cause came from a most unexpected source, in the form of Bret Harte's now well-known poem on "The Pliocene Skull," in which the skull finally speaks for itself and fixes the place of its origin:

> Which my name is Bowers,
> And I'd take it kindly
> If you'd send the pieces home to old Missouri.

Whitney's final summing up of the evidence relating to the famous skull[1] did not appear until thirteen years after his first paper, and

[1] Whitney, J. D., Auriferous Gravels of the Sierra Nevada, 1879.

in this he presented what seemed to be a complete case in favor of the authenticity of Mattison's find in the shaft on Bald Hill.

With the final report on the skull there was also published a most interesting array of supporting evidence showing the presence of human remains and relics in auriferous gravels of approximately the same age as those from which the Calaveras skull was reported. The finds discussed by Whitney included stone mortars and pestles, obsidian axes and arrow-points, beads, and human bones, the occurrence of all of which was vouched for by the testimony of trustworthy and unprejudiced men. The mass of evidence advanced by Whitney seemed, taken at its face value, to leave no room for doubt that man had lived in this part of the world at a very early time.

Some years after the publication of Whitney's principal paper on the question of early man in America, the whole problem, including the cases investigated by Whitney, was carefully reviewed by Professor W. H. Holmes,[2] according to whose judgment the evidence indicating the existence of man in California during the deposition of the auriferous gravels seems insufficient.

The writer's attention was first attracted to the question of auriferous gravel man by coming into contact with several persons of high standing who knew definitely of stone implements being obtained from deep gravel mines since the completion of Whitney's studies. At that time a list was compiled which included about a dozen apparently well authenticated instances of occurrences of human remains in the auriferous gravels. The problem taken as a whole seemed to the writer to present as remarkable a case of absolutely contradictory evidence as ever appeared in science or in law. On one side men with high reputation for veracity gave affidavits to the effect that they had personally seen human bones and relics taken from undisturbed layers in supposedly ancient formations. On the other hand, scientists claimed that such occurrences were impossible. The positiveness of the statements suggested the possibility of there being some truth on each side, and in 1894 a campaign was entered upon to determine if it were not possible to arrive at a satisfactory understanding of the evidence.

While it has been clear from the beginning of this investigation

[2] Auriferous Gravel Man in California, 1899.

that only the most conclusive proofs of the presence of human remains in the older formations could have any weight against the accumulated scientific evidence indicating its improbability, the writer has also been unwilling to suppose that the miners of California are more inclined to play practical jokes, or the scientists of the West more easily fooled than those in other portions of the world, or that the word of the average man with reference to scientific matters is less reliable here than elsewhere.

Without digressing too far from the question of the Calaveras skull, it may be said that the probabilities as to the history of man as indicated by scientific investigations elsewhere do not seem to be contradicted by any evidence thus far obtained in California. It is probable that the remarkable occurrences of human remains which have been reported in this state owe their origin in a large measure to the exceptional conditions existing in California during the progress of placer-mining on a gigantic scale. In regions where implements and skeletal remains left by the aboriginal inhabitants were abundant, many relics were washed down or moved about so that they came to be found in most unexpected places.

In attempting to obtain evidence as to the origin of the Calaveras skull particularly, the question arose whether an examination of the matrix in which the skull was enclosed when it came into Whitney's hands might furnish conclusive evidence for or against the view that the skull came from the auriferous gravels. In 1892 the skull was examined to determine whether any clue as to the nature of the occurrence of the specimen could be obtained from an examination of the enclosing matrix. The gravel was found to consist almost entirely of angular fragments of rock, quite unlike the well-worn pebbles which make up the mass of the auriferous gravels in strata corresponding to the level at which the skull is supposed to have been obtained in Mattison's shaft. Contrary to Whitney's statement the matrix indicates quite conclusively that the skull could not have come from the auriferous gravels under Bald Hill.

Fortunately the investigation which furnished evidence regarding the nature of the matrix of the skull also gave some suggestion as to the probable place of origin. As had been shown by Whitney, the skull was found to be incrusted with a thin layer of calcareous material, which also partly filled the pores of the bone, and formed small veins or plates in the matrix. Such incrustation and infiltra tion with lime deposit as is seen here may occur in a variety of situations, but it is found most commonly on specimens entombed in deposits in caves or in rock fissures. In agreement with this is also the nature of the angular rock fragments in the matrix. Those in cave deposits may be water-worn, but generally include a large percentage of angular, unworn pieces, only recently broken away from the surrounding rocks. Farther suggestion regarding the cave origin of the skull is given by the presence in the matrix of a number of snail-shells, rodent bones, and a snake vertebra—remains that have been very commonly found in the cave deposits of the California region in the course of recent investigations carried on in them.

In close conjunction with the writer's first examination of the Calaveras skull there came from different sources two instructing statements which were considered to have an indirect bearing on the problem of the skull. At one of the scientific meetings in Washington in the winter of 1902, Professor W. H. Holmes exhibited two peculiar skulls partly covered with a calcareous incrustation, and recorded as having come from a cave in Calaveras county, California, the exact locality not being given. On the same day that these specimens were exhibited a member of the Whitney Geological Survey of California told the writer that numerous skulls with calcareous incrustations were obtained from caves in Calaveras county by members of the survey, but he had no knowledge as to what had become of the specimens. Professor Holmes had previously, in 1901, suggested the possibility of cave origin of the skull which Whitney received.

A general statement of all the evidence bearing on the possible cave origin of the Calaveras skull, together with some suggestion as to how the skull might have come into Whitney's hands, was read by the writer before the meeting of the American Anthropological Association in 1903. The suggestion as to cave origin has more recently been elaborated by several writers[3] and seems to be generally accepted, though it will probably never be possible to prove it absolutely.

If the Calaveras skull came from a cave, it still remains to show

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[3] Hrdlicka, A.; Skeletal Remains Suggesting or Attributed to Early Man in North America, 1907.

Sinclair, W. J.; Neocene Man in the Auriferous Gravels of the Sierra Nevada, 1908.

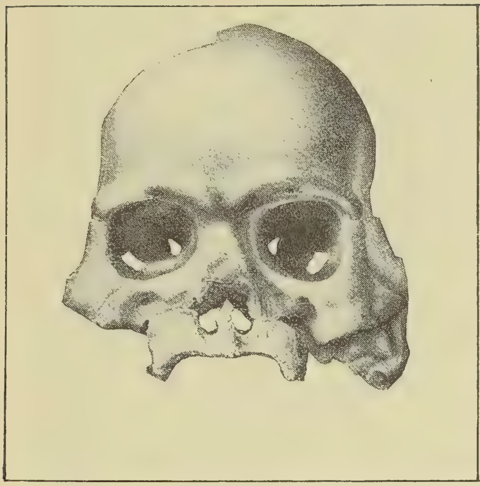
how it finally passed into Whitney's possession as a relic from the auriferous gravels. In this connection several interesting items of information have come to light. One of these seems to show that even if a joke had been played upon the miner, Mattison, this particular joke had failed to reach the geologist Whitney. Some years ago Professor F. W. Putnam exhibited a small photograph, showing the skull in nearly the condition in which it was first seen by Whitney, to residents of Angels Camp who claimed to have been concerned in putting the joker skull into Mattison's mine, and was informed that this was certainly not the skull which they had put in the shaft. In this connection Dr. Sinclair has recently shown that skulls from the locality at which the jokers were supposed to have obtained the specimen used to fool Mr. Mattison are buried in a matrix quite unlike that which covered Whitney's specimen. According to these statements, behind which it does not seem necessary to go, it may be supposed either that several skulls were placed in the shaft by independent parties, or that in the several changes of ownership between Mattison and Whitney, the original skull disappeared, and another specimen was unwittingly substituted.

After so long a lapse of years, it will probably never be possible to trace out the history of the Calaveras skull with certainty, but at least one circumstance suggests an unintentional substitution. According to Whitney's account the skull was in the possession of Dr. Jones of Murphy's not longer than a few months. Mr. J. L. Sperry who was living in Murphy's, and resided just across the street from Dr. Jones at the time the skull was found, has on several occasions minutely described to the writer and to others his first view of the Calaveras skull. According to his description, Dr. Jones one day suddenly appeared in his doorway with the skull, which was covered with dust and cobwebs. He was very much disgusted over something connected with the specimen, that he seemed to think had been lying about somewhere for a long time. Jones pitched the skull out into the street, but afterward recovered it. The presumption is that this specimen had been stored away in Dr. Jones' office, or elsewhere, longer than the period which seems to be allowed for its possession by any one of the several parties through whose hands it is supposed to have passed in a comparatively short time. It may easily have been one of the numerous cave specimens, which had been obtained in this region. This specimen it was, which was sent to Whitney in practically the condition in which it is shown in the bottom picture on the first page of illustrations following this paper. It is improbable that we shall ever know with certainty the true origin of this specimen, but whatever be the actual place in which it was entombed, it is probable that, had there been no suggestion of its having been derived from the auriferous gravels, anyone familiar with California cave specimens would, at the first glance, have considered it a cave relic of rather ancient though uncertain age.

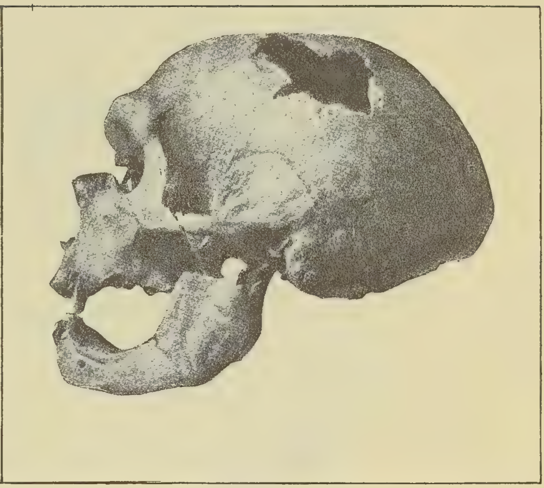
Considered as a cave relic, the Calaveras skull may possibly represent a race inhabiting the Californian region at a really remote historical period. The cave investigations which have been carried on in this state during the past few years have shown that at several localities, ranging from northern California down through the foothill region of the Sierras, human remains are found embedded in cave deposits which have an appearance of antiquity, though they probably belong to the present or the recent geological period. In Shasta county human bones were found embedded in the stalagmite floor of a remote gallery in the Stone Man Cave. At Murphy's, Calaveras county, human bones covered with stalagmite were found in close proximity to those of extinct animals, though probably more recent than the extinct creatures. At Hawver Cave, in El Dorado county, Dr. Hawver has recently found human bones covered with stalagmite and embedded in hard, cemented cave deposits more than twenty feet below the surface. It may be repeated that these occurrences do not individually necessarily imply any considerable age geologically considered, but the impression given by the numerous cases observed is that the period which has elapsed since entombment may be comparatively long historically, or measured in years.

An interesting confirmation of this suggestion as to the age of some of the cave remains of this state has recently been obtained by Dr. C. Hart Merriam, Chief of the Bureau of Biological Survey, United States Department of Agriculture. Contrary to the view that the skeletons found in the limestone caverns represent cave burials by Indians now living in this region, Dr. Merriam finds, in his study of the Mewuk Indians living on the western slope of the Sierra, that they look with horror on this method of burial, and have certainly not practiced it. They are, however, aware that skeletons exist in the caves, and believe the caverns to be inhabited by a stone giant called Chehalumche, who leaves the caves at night to search for food. Human beings are the prey which he likes best. The victims are carried to the giant's lair to be eaten, and it is the bones of these unfortunate persons that we now find in the caves.

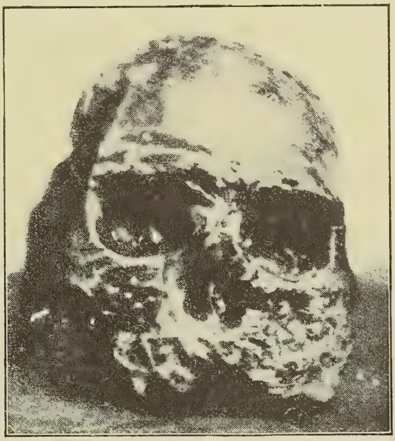
The mythology of the Mewuk as obtained by Dr. C. H. Merriam indicates that these people have lived for a long time in the region where we now find them. Their myths describe the creation of the ancestor of the tribe in the region where they now live; and this, in connection with the fact that the Mewuk speak a language not known in any other part of the world, shows that these people have probably occupied their present home for a long time. As the cave burials must have occurred before the Mewuk came to occupy this country, they must date from a remote period, which in Dr. Merriam's opinion is to be measured in thousands of years.



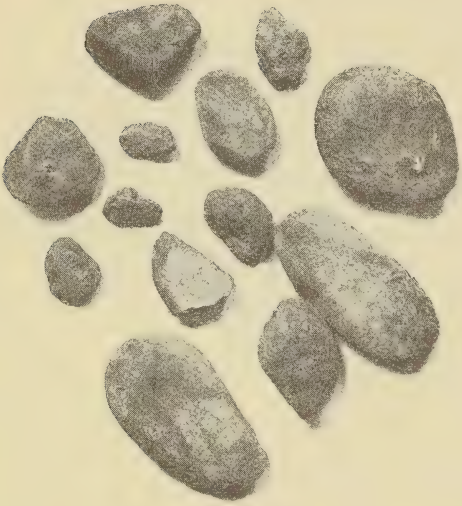
Calaveras skull showing prominent forehead as in large-brained man of the present geological period. From Whitney.



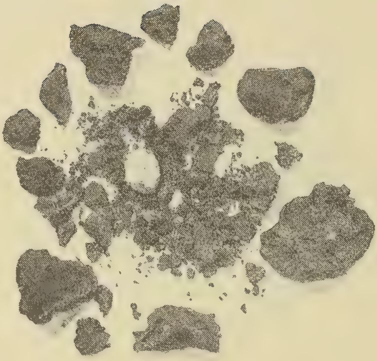
Skull of a small-brained primitive man of the geological period preceding the present. From a cave in southern France. After Boule.



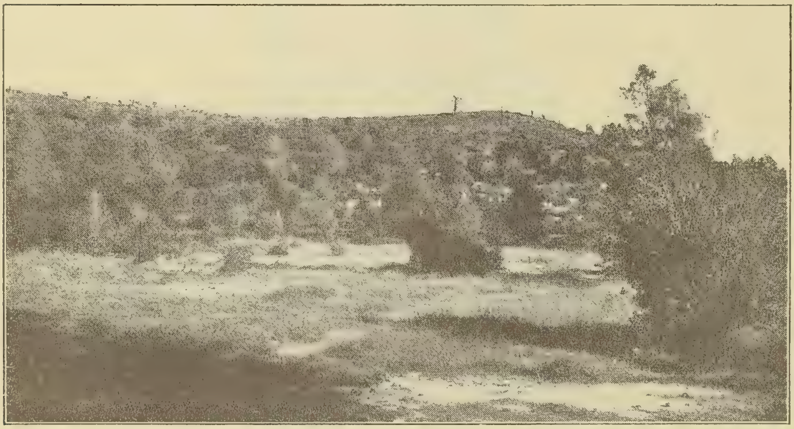
Calaveras skull before the original enclosing matrix had been removed. From a photograph in the University of California library.



Typical rounded water-worn gravel from water level below volcanic rock on Bald Hill.



Rock fragments from the enclosing matrix of the Calaveras skull. Many angular pieces.



Bald Hill, near Angels Camp. The shaft in which the Calaveras skull was found is on the slope of the hill below the pine tree on the crest.

THE CAVE OF THE MAGIC POOL

THE MEANING OF A FRAGMENT

Illustrations from Photographs by the Author

THE story of life as it comes to us through the ages must in certain cases be built upon fragments. This does not signify that it is therefore untrustworthy. Nor should it be assumed that it is always fragmentary. A clear understanding of the record requires appreciation of the importance of our evidence, even if it rest upon meagre data. The following incidents in the course of cave exploration in a search for knowledge of ancient life in California illustrate conclusions which seem not to be avoided, though based on scanty materials.

It was a part of the programme in this investigation to examine every suggestion of evidence that might lead to discovery of caverns in which remains of ancient life could be entombed. In searching for new clews we learned from Wintun Indian workmen of a cave long known because of reputed magic qualities of a pool in one of the larger chambers. Though the story came to us repeatedly, it was always in the same form: of a cave with a magic pool called in the Indian language, "Samwel," and that it was visited for the potency of its water in bringing good fortune. Always it concluded with an account of three maidens who failed to obtain good luck at the pool, and were told by a very aged woman of other water with stronger magic. This second pool was said to lie in a remote chamber, and to escape discovery excepting for the most adventurous. In the course of a long search for this more powerful charm the three maidens came to a pit with sloping borders. As they approached the entrance, one of them slipped on the moist rock. The others tried to save her, but she fell screaming into the darkness. They heard her "strike and strike again, and all was still." A rescue

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party was unable to reach the bottom of the well and efforts to find the maiden were abandoned.

The story of the cave of "Samwel" seemed to present the possibility of a cavern of considerable magnitude, in some part of which remains of ancient life might be discovered, and plans were therefore made to visit this locality. Though it lay in a wild, unsettled region, there was little difficulty in locating the entrance of the cave. About sixteen miles above the mouth of the McCloud River an extensive series of galleries was found opening on the face of a limestone bluff three hundred and thirty-five feet above the river. Nor was there difficulty in finding a pool located in the third chamber. Whether or no its waters gave us the good fortune, it is true that we succeeded also in the real objective of our search. On the floor of the cavern there were ancient deposits containing numerous bones and teeth representing animals of California in a period probably antedating the present by many tens of thousands of years.

The second pool and the deep pit we did not find. Three expeditions failed in search for the well, and in the attempt to verify the story that had led us to this cave. Neither fascination of following the lead of a legendary description nor lure of unexplored regions could bring success. In the third attempt we made heroic efforts, crawled through passageways so narrow and tortuous as to seem impassable, and entered chambers apparently never before visited by white men; but without obtaining evidence indicating that the legend was based on fact. After the last trial the exploring party returned to camp, where excavations were under way at Potter Creek Cave near the mouth of the McCloud. Mr. Furlong, one of the members of the staff, remained at Samwel Cave to investigate the fossil deposits discovered in chambers near the main pool.

On the day following our return, a message was received from Furlong stating that he had found the deep pit, and requesting that I return as early as possible with all the rope-ladder and rope available. The next afternoon I arrived at Samwel Cave camp with a pack-horse carrying fifty feet of rope-ladder and all the loose ends of rope to be obtained in camp.

Furlong told me that on entering the cavern shortly after our departure he had noticed a narrow ledge along the wall of the second chamber. On following this shelf he discovered a series of galleries not seen in earlier exploration. At the end of these passageways was a pit with sloping borders. Rough measurement indicated a depth of approximately ninety feet. After transmitting word to me by a roundabout route, Furlong had returned to the cave and begun preparations for our descent. In the rock near the edge of the well he drilled two deep holes so placed that the steel drills standing in the floor could give firm support to a ladder.

We spent the evening and the next morning in constructing an additional fifty feet of ladder out of pieces of rope, and such short sticks of wood as could be found around camp. It was then something of a burden to transport this equipment to the edge of the pit. The ladder was firmly fastened. A few pieces of burning paper were dropped into the well to make certain that the air was safe for breathing. Then we drew straws for choice as to order of descent. Furlong's straw was the longer and he elected to go first.

As he descended, Furlong described the cavern opening to the light of his candle. "It widens as I go down," he said, "from a diameter of ten feet at the top to a great chamber below. And here as the ladder begins to hang free of the wall is a sharp projecting spine of rock that thrusts itself between the ropes and makes climbing difficult." Then after a longer wait, during which he moved somewhat unsteadily over the rickety lower fifty feet of odds and ends of rope and firewood, I heard the hobnails of his heavy shoes grate on the stone floor. It was a critical moment, as I waited to learn whether the maiden whose tragic story had led us to this adventure was a reality or only the product of fertile imagination. Suddenly, with voice raised by excitement, Furlong called up: "There's a mountain-lion at the foot of the ladder." The swift train of thought in the ensuing moment I often recall, and the various possibilities that presented themselves. To go a little less than one hundred feet down an imperfectly constructed rope-ladder to help a man fighting without weapons against a puma offered little hope of real assistance. If the lion should win, would it attempt to climb the ladder? Before any plan was framed that seemed to have value under these special circumstances, Furlong shouted: "It is a fossil mountain-lion embedded in the cave floor." Then, almost without pause, and with intonation indicating that he could hardly believe his eyes, came the words: "And here on the floor below the opening is the skeleton of the Indian maiden."

As quickly as difficulties of descent would permit I climbed over the edge, and down past the sharp spine of rock that thrust itself against the ladder. The well widened to a great chamber in which our unsteady ropes hung clear. Swinging free at the bottom I almost stepped on the skull of the mountain-lion. A few feet beyond, Furlong was bending over a delicate human skeleton that lay huddled in a dark heap. The body had not moved from the spot where the girl crashed against the solid stone immediately under the opening. Only the bones and a film of black mould remained. Here and there a beginning crystal of stalagmite gleamed in the dark covering, but the lapse of time had not been great enough to allow the lime deposited from dripping water to form a complete incrustation.

This was the end of the trail we had followed so long. Was it also the end of the trail the maiden sought to follow? Could it be that in the tragedy which terminated her search she had found the pool of greater magic? As we asked this question our candles were held higher, and for the first time we looked about the cavern.

A part of the bottom of this huge chimney was covered by masses of rock with lime incrustation. The broad floor was partly incrusted with sparkling stalagmite. The lowest area carried a layer of soft brownish clay.

Scattered about wherever we looked were skulls and parts of skeletons of many animals, some so deeply covered with lime as almost to merge with the floor. The mountain-lion at the foot of the ladder was heavily encased and cemented in the rock. Near the skeleton of the maiden was a large skull with gracefully curving horns. No head like it had been known to man before. Close by lay another creature with wide sweeping ox-like horns—a type of animal then seen for the first time. Across the cave was a perfect skull of a bear, incrusted and cemented to the floor. No human had known this type alive or dead. Spread before us was a veritable museum of ancient life including also deer, squirrel, porcupine, raccoon, fox, rabbit, and many others. We wandered about the cavern attracted by each new treasure, but soon exhausting the means of expression that seemed adequate for this experience.

The remains which we saw on the cave floor belonged to an assemblage of animals not previously known. They represented a stage in ancient life of America long antedating the fauna now ranging over mountains and valleys of northern California. Shut off from the outside world in this chamber we stood as it were in the immediate presence of a remnant of the past that through protection of these walls had remained to give its testimony.

The remaining traces of original organic material covering the skeleton of the Indian maiden, and the incomplete lime incrustation upon the bones, indicated that entrance of the girl into the cave had been at a very recent period compared with that of the strange creatures among whose incrusted remains she had come to rest.

Nowhere in the chamber was there evidence of standing water, unless it once occupied the area now covered by soft clay. The maiden who led us on the trail of the magic pool failed in her special mission, but had marked the way to knowledge of mysteries as great as those she sought to fathom.

For hours we studied the cave and its treasures. Then seeing that it was late we made preparations for return to camp. In the course of the afternoon I had stated to Furlong that the study of this cave and its many fascinating problems was to be his task. As we were leaving he remembered that C. Hart Merriam, the great authority on bears, was in our camp at Potter Creek, and that his judgment might be had on the characters of the bear whose skeleton was frozen in the cave floor. The skull was straightway pried loose, wrapped in my corduroy coat, and fastened to the foot of the ladder.

Weary with the long day's work we made our way carefully to the galleries above. At the edge of the pit we drew up the ladder with the bear skull attached. It was heavy. We pulled together. Then Furlong held fast while I laid back the folds of the ladder as they came over the edge. After seemingly interminable hauling, the last rung appeared with the cord fastening the bear skull. I lifted back the last fold. When I turned again Furlong was standing with one hand reaching over the well, holding the end of the ladder, but rigid as if turned to stone. The corduroy coat and the bear skull were gone. Suddenly there was a crash, and I realized that the cord which tied the skull to the ladder had parted just as the last rung was lifted over the edge. Mr. Furlong prefers that discussion of what was said in the ensuing moments be omitted. He insisted on lowering the ladder, and descended to learn the fate of his new bear. The skull was spattered pretty well over the entire floor, but with unbelievable care Furlong gathered up every piece. No fragment escaped; all were wrapped in a new bundle and once more the bear journeyed to the top of the ladder. When many weeks later the fragments reached the laboratory, he fitted them together with such skill that the mounted specimen as we see it now appears practically without flaw.

The absorbing experiences of the day, pieced out with the escape of the bear and its recovery, had made us lose the count of hours, and arrival at the outer entrance did not diminish immediate usefulness of our candles, as it was night. We stumbled into camp conscious mainly of an overpowering need of sleep. Furlong found a pan of rice and a can of tomatoes cached in the ice-cold water of the McCloud. They sufficed to meet a hunger largely overwhelmed by weariness. Lying back on my sleeping canvas, for a moment I was conscious of the piercing brilliance of starlight, and a babel of muffled voices from the river—and then the bright light of morning wakened us.

Many days were consumed in preliminary study of the deep well and its treasures. Furlong then began systematic gathering of the abundant remains of ancient life on the floor. With this work under way the remainder of my time was spent in exploring nooks and crannies for further evidence regarding the origin and mode of entrance of the creatures whose bones were found in this chamber. It seemed inconceivable that the large animals here could have found their way in by the long dark galleries leading to the small aperture above, nor was there piling up of skeletons immediately below the mouth of the pit such as would have occurred had the bodies fallen in. There seemed good reason for assuming that at some early time there had been a lower passageway through which bears and pumas, and the creatures upon which they preyed, had reached the cavern—an opening that later changes had closed and sealed.

The search led me finally to a narrow space behind a number of large rock masses on the extreme margin of the chamber. Among the loose blocks forming the floor were numerous parts of skeletons. There were porcupine, gray fox, a tooth of an extinct ground-sloth whose near relatives were found in Texas and South America, and then among the bones appeared a portion of a human tooth. Instantly this fragment raised question whether man had been present at the time the ground-sloth and other animals now extinct had inhabited this region.

There was at least one other possibility. With the specimen in my pocket I climbed over the rocks toward the skeleton of the Indian maiden. As I approached my mind centred on the chance of proof that this particular portion of a tooth from a remote part of the cave belonged to the remains on the floor below the entrance. If the irregularly fractured end of this fragment should fit with perfect smoothness upon a roughly broken tooth in the skeleton of the Indian girl, there would be no need of further answer to questions concerning presence of the human tooth among the bones of these ancient animals. It would be clear that the human individual represented by the fragment was a comparatively recent arrival and not a contemporary of the strange extinct creatures whose skeletons were here seen for the first time.

With the tooth in my hand I bent down and turned the skull till the teeth were all in view. A portion of one was missing. The broken end of the fragment was brought into contact with the fractured tooth in the skull. The irregular ends touched and grated as their unevennesses failed to match. A slight twist and the surfaces seemed to melt together. No smallest roughness held them apart. There could be no doubt that they belonged together.

With the fitting of the fragment into its place in this skeleton there flashed into mind the ending of the Wintun story of the maiden who sought the pool of stronger magic. "She fell and struck, and struck again and all was still." I looked up to see the sharp spine projecting below the mouth of the pit. As if the drama were being re-enacted, I saw her strike in mid-air on that rock, a fragment of a tooth flew wide across the well—the body "struck again" upon the floor, "and all was still."

To the Wintuns in this region we gave the story of our search for the well and the second pool. In turn, they told us something of the family of the maiden who perished in the pit between one and two hundred years before our coming. The Wintuns asked to take the skeleton, and as much of it as was carried up the rickety ladder was entombed again with ceremony where the crystal waters of Nosone Creek join the McCloud.

Summer ended before work in the cave of the Indian maiden was completed. In the meantime we had tried by many methods to locate the suspected ancient entrance through which the numerous animals in the floor could have entered. A stalagmite-covered slope next the wall suggested a stream of earth coming from a passageway which it might have filled. A cut was made. Below a thick lime incrustation there was earth and gravel. The heap led to an opening in the solid wall, and then upward through a chute penetrating the limestone in which the cave had been formed. As work proceeded there was grave danger from caving, as the earth was above us, and means were not available for adequate protection. Not wishing to risk serious accident, further examination of this gallery was postponed to another season.

A year later, during the last stages of excavation, we made calculation as to the nearest point on the outer wall, hoping that by this means an ancient outer entrance might be discovered. A shaft was sunk at the point located. At eleven feet it entered gravel through which oozed a strong draft of cold air. Following the gravel layer horizontally the draft increased. Suddenly gravel and earth gave way and we were digging into a small chamber closed on every side. The thrill experienced was of that peculiar type that comes only in facing the mystery of a hidden room, perhaps shut off for ages from the outer world. What secrets of the past might it hold?

The cavity we had entered was a small chamber closed on every side. It gave no evidence of a passage extending into the mountain or toward the cave in which our excavations had been conducted.

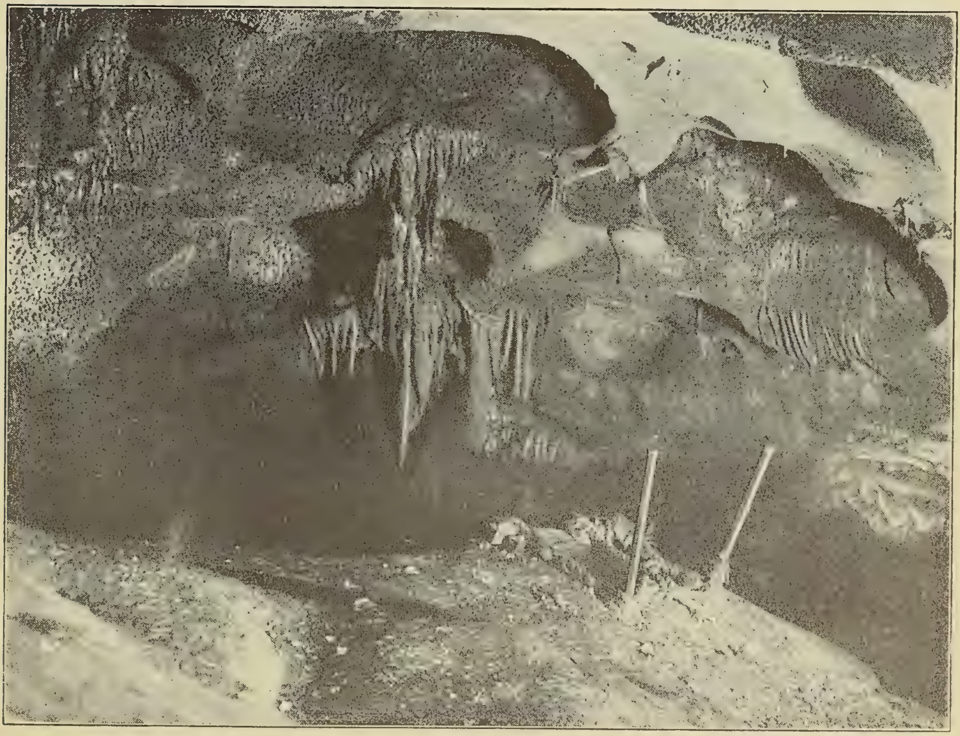
Boynton, the athlete of the party, volunteered to climb back to the main entrance and down to the cave of the maiden to discover whether signals could be heard through the intervening rock. It seemed only a moment after his leaving that a sharp tap came from a point near the inner wall of the hidden chamber. It was followed by other rappings, each seeming nearer than the last. The pounding stopped, and there was a rasping suspiciously like scraping of heavy shoes dragging behind a man crawling through the narrow opening between the cave of the maiden and the lateral chute into which we had dug in the previous year. Furlong was remarking that the sound came from a point only a few feet distant when, with unbelievable distinctness, we heard Boynton say: "For heaven's sake step easy or you'll come through." Without stopping to reply I seized a shovel and stabbed sharply into the earth at my feet. The floor gave perceptibly. A few more strokes and we saw the light of Boynton's candle for an instant before a rush of cold air extinguished his light and ours. A moment later the wind died down. The candles were relighted. The opening was widened, and the smiling face of Boynton appeared as he climbed through.

Scant eighteen inches of earth and gravel had separated the highest point of excavation in the previous summer from the floor of the hidden chamber. The chute, the hidden chamber, and the shallow outer grotto partly filled with earth in which our shaft was sunk, formed a passageway reaching through the limestone cliff to the cave of the maiden. When, later, the earth was partly cleared the opening showed itself sufficiently large and easy of travel for ready use of the animals discovered in the cave. There could be no doubt that one of the mysteries of the cavern was solved. A large part, if not all, of the creatures we had found entered by this route. Like the unfortunate Indian girl, the mountain-lion at the foot of the ladder may have lost its footing at the mouth of the pit and fallen to the floor below. Other animals possibly entered by passages as yet unknown, but the wide and relatively direct way furnished by the opening we had just followed was clearly the principal means of entrance for the ancient population.

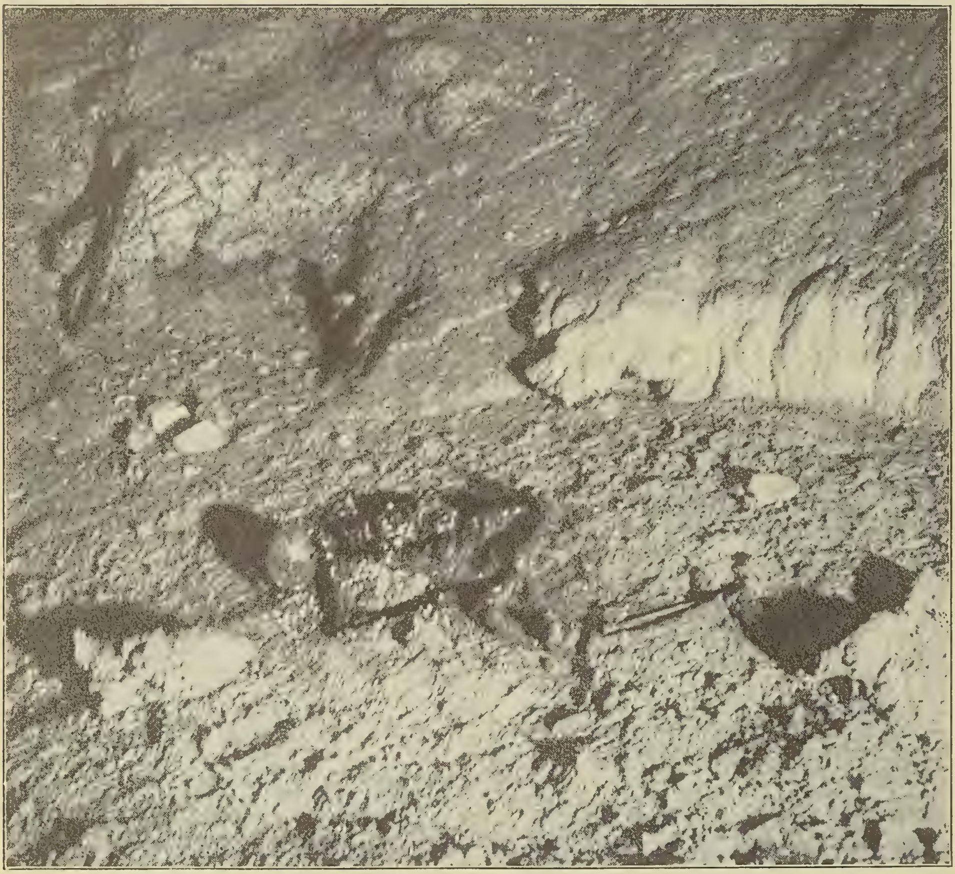
How long this buried entrance had been closed, and the precise time at which it was open, we may never know in terms of years and dates such as are used in description of events and periods of recent human history. When the creatures found resting on the cave floor lived and were moving back and forth through the ancient entrance, the face of the land and the life roaming over it differed from what we see to-day. At the time the entrance was blocked the landscape approached more closely its present features. When the Indian maiden, clambering over the rocks to the upper cave, looked back toward the blue river for the last time, the early entrance was already lost to view behind a mask of débris.

Such are the outlines of a story that as yet we read only in part. Lured by the possibility of bringing to her use something of the mysterious power she saw everywhere in nature about her, the Indian girl opened the way to mysteries which the obscuring veil of time had seemed completely to protect. The fragment of a tooth that parted, when she "struck and struck again," brings before us in clear reality the maiden in her strange adventuring, who joined the sleeping company of ages past, and led us to a place where we could have a fleeting vision of the world in other days.

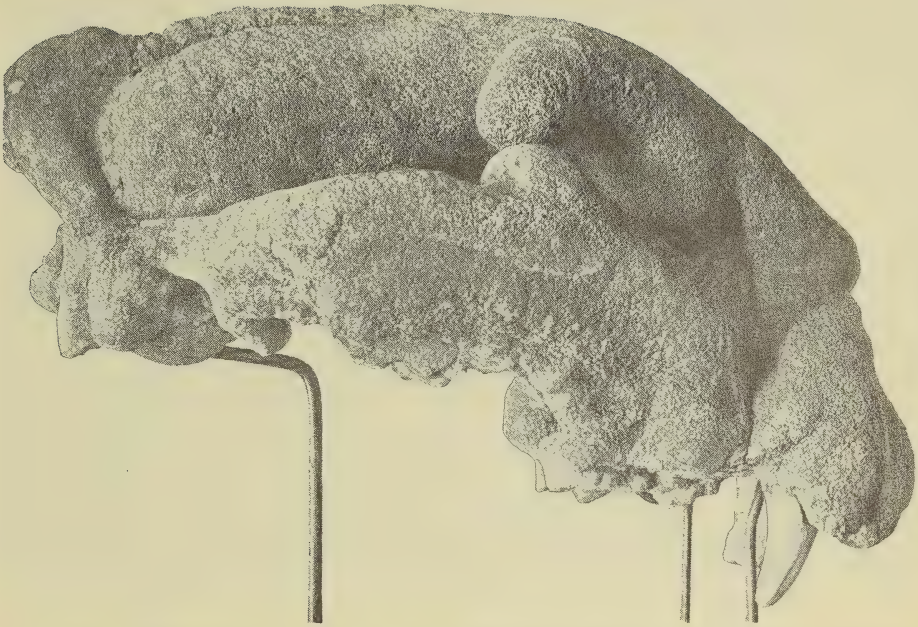
Entrance to the first, or outer, chamber



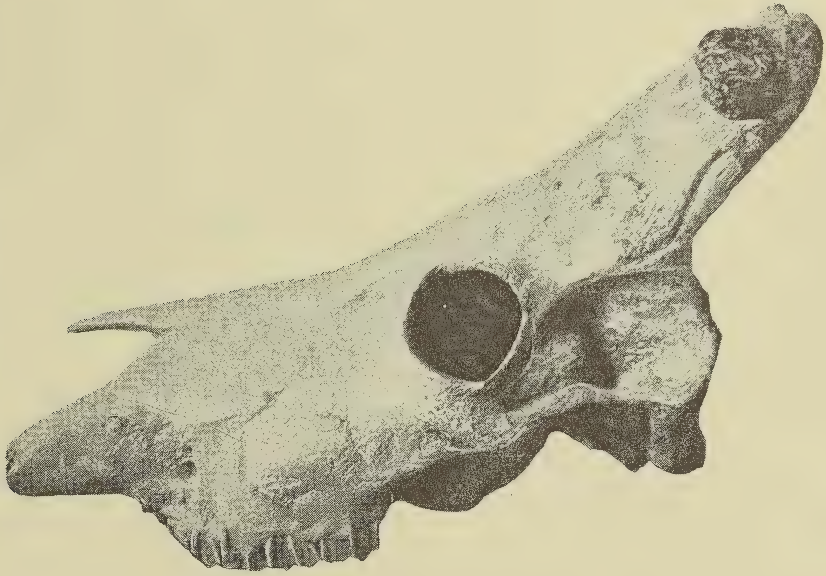
Entrance to the pit into which the Indian maiden fell



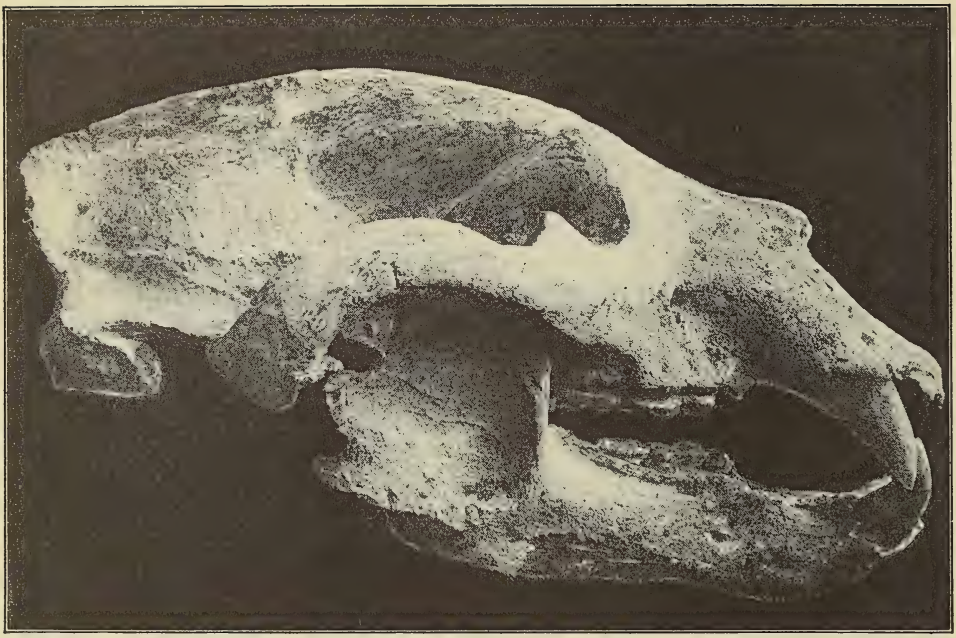
The skeleton of the Indian maiden on the floor of the cave



The skull of the mountain lion at the foot of the ladder, with its original covering of stalagmite



The goat-like animal with curved horns that lay embedded in the stalagmite near the skeleton of the Indian maiden. (Side view)



The bear skull that escaped and was smashed on the cave floor. Shown as it appeared after repair.

Mr. Boynton coming through. The first living being to use this passageway since it was choked in a remote period.

POOLS THAT REFLECT THE PAST

A DIARY written on the first Spanish expedition to California contains the description of a peculiar swamp of asphalt or of brea which was reported to flow like melted rock from underneath the earth. In a later stage of exploration the first transcontinental railway survey party found in the same region a locality where mineral pitch poured from the ground in great quantities and sometimes formed large pools or lakes. One spring was pictured as coming from a small opening around which the asphalt spread over a circular space about thirty feet in diameter.

This region of the black springs, known as Rancho La Brea, near the site of present-day Los Angeles, came in time to be operated by the owner as a source of asphaltum used for roofing and paving. Chinese laborers dug the best parts of the deposit from the pools and cleansed it in large vats. The impurities were separated by heating the mass to a temperature at which the liquid asphalt could be poured into moulds, leaving a residue consisting of tree stems and bones. The trees were laid aside by the workmen for use as firewood. The bones were thrown on refuse heaps, which came ultimately to contain thousands upon thousands of fragments of skeletons representing many kinds of animals.

Major Hancock, the owner, was familiar with the way in which all manner of beasts and birds were caught and buried in the brea. He had seen squirrels, chickens, ducks, calves, and colts walk unsuspectingly upon the surface of the sticky mass, fall, and struggle until they were gradually ingulfed. It was a common experience to find cats, dogs, and coyotes lured by the struggle of animals thus trapped and themselves become victims of the pool. The considerable losses of fowls and stock from the ranch gave some indication of the extent to which remains of creatures buried in this way might accumulate in the course of years.

It was known to Major Hancock that many of the skeletons found in the pits which he excavated differed greatly from those of barn-

The Living Past, chap. II, pp. 29–38. New York: Charles Scribner's Sons, 1930.

yard animals, and from the coyotes, squirrels, and other wild life in the valley. Some of the bones were too large to belong to any creature known to have lived in California, and the skulls of many birds and four-footed animals discovered were entirely different from those of all living things with which he was acquainted.

A naturalist from Boston, who visited Rancho La Brea, was asked to probe the mysteries of the asphalt. He found the innumerable skeletons in the pits to be largely those of animals no longer living anywhere on the earth. A great scimitar-like tooth he described as that of a gigantic cat, similar to remains found only among the relics of ages long preceding historical times.

After the death of the owner, and the stoppage of work on the asphalt deposits, the explanation which the naturalist had given for the presence of bones in the brea seems to have been forgotten. Thirty years later a new series of investigations brought out again the fact that the asphalt pools were the tombs of a vast number of creatures that had inhabited this region at a period probably antedating the present by at least one hundred thousand years. The skeletons buried in the brea were shown to represent not only an immense number of individuals, but a great variety of creatures as well.

Among the animals recognized were such strange forms as the elephant and camel, together with extinct horses and bison. With these beasts, of which we know similar species living in other parts of the world to-day, there were mastodons, great ground-living sloths as large as rhinoceroses, gigantic bears differing from every living type, lions exceeding in size all other felines living or extinct, a multitude of cats with knife-like fangs, a huge extinct wolf probably the largest of his tribe, an eagle-like bird greater than the condor, and a multitude of other birds and beasts entirely strange—even to those most deeply learned in the animal life of the present world.

The discoveries at Rancho La Brea told one of the most remarkable known stories of the life of a past period, and naturally led to extended scientific investigations, involving excavation of the asphalt pools and reassembling of the skeletons unearthed. The results brought out a vast amount of material, which has been estimated at approximately 3,000,000 bones.

In this multitude of specimens every detail of structure is retained. The preservation of bones and teeth is not farther from perfection than in the remains of recently dead cattle bleaching near by. Not only is there perfect conservation of the material composing the skeletons, but with this is indubitable evidence of many aspects of use or action in the life of the individual animals represented. Cutting and tearing teeth of wolves and lions are seen worn down where they rubbed upon each other, or against the bones and softer tissues of the creatures upon which they preyed. Molars of bison, camels, horses, and elephants are grooved and scored by mastication of their great bulk of vegetable food. There are the bitten and broken bones of many birds, wolves, and tigers. In some of these, imperfect contacts led to healing in such manner as to leave crooked or twisted limbs. Abundant specimens show diseased tissues of many parts of the skeleton and teeth.—A wolf with a broken foot, and a sabre-tooth tiger with fractured and shortened arm, tell each a story for which conviction does not depend upon intricate logic or abstruse scientific theory.

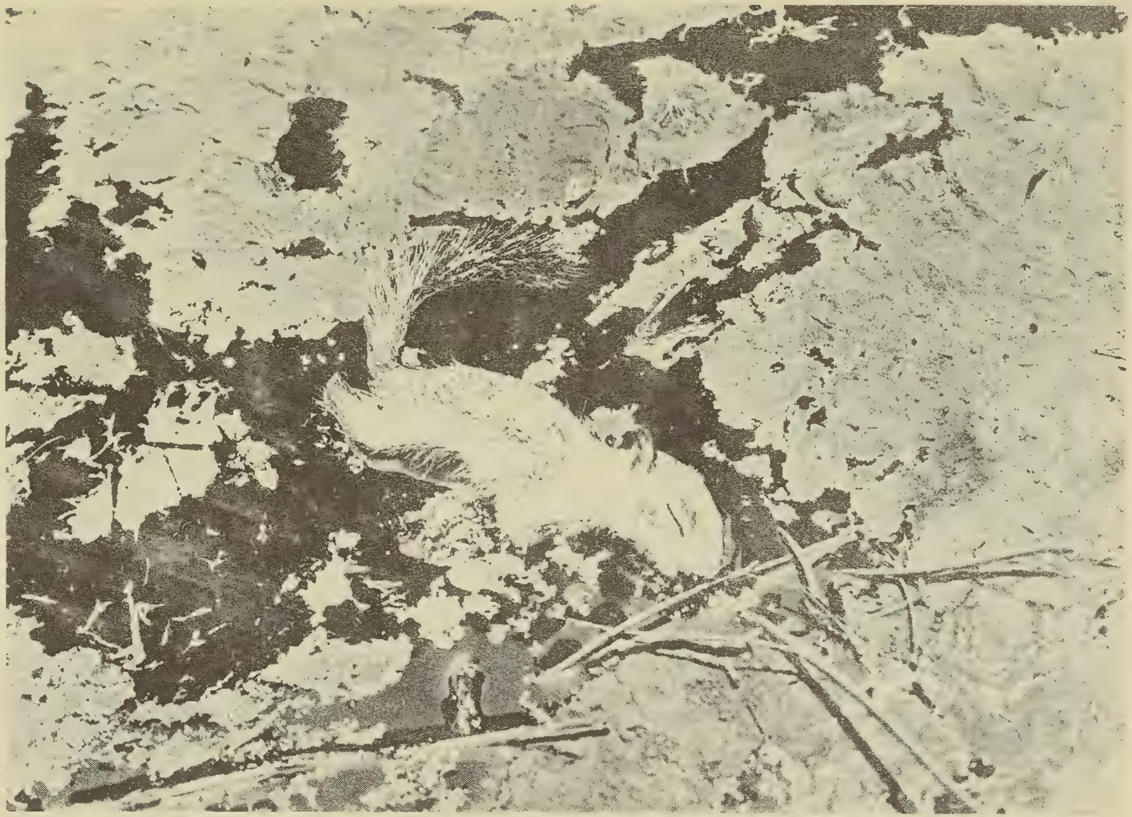
One also looks intimately into the changing stages of life of these creatures from babyhood to old age. Lion and tiger cubs and baby wolves show every step in development of skeleton and dentition from the time when the milk teeth just began to appear, on through the many advances to complete replacement by permanent teeth, and into the years of decadence and senility.

Out of early excavations in the pool there came one day the skull of an ancient tiger with sabres broken and shattered to the roots. The ends of these teeth were worn and blunt, as also the front teeth opposing them in the lower jaw. Through long wear produced by biting upon its food in the form of other creatures on which it fed, the fractured blade of one great tooth had been cut down to a smooth broad surface. Also shattered and splintered, the other sabre showed less wear on the broken end. This second tooth had maintained itself intact long after the other was broken. But at last it fractured in an unduly heavy or misdirected blow. Instead of carrying death through the swift, sharp strokes of its sabres, the habits of life of this animal were changed, as also in all probability the nature of its food. The tremendous roots of the sabre teeth were shrunken, and the bone around them had shrivelled. It was an old, emaciated, sunken-cheeked animal that left us this record of its last adventure, in which strength, and skill, and courage were inadequate.

In the multitude of individuals buried here the vast predominance of types that fed on flesh seems almost beyond belief in contrast to the smaller group of those which formed their prey. But to the flesh-eating animal these pools were continuously baited traps. Any creature captured and struggling in the tar was a lure. The young and inexperienced, the crippled and incompetent, and the aged ones with failing limbs, seem under the stress of hunger to have risked the effort to obtain a meal from prey that lay within their easy reach.

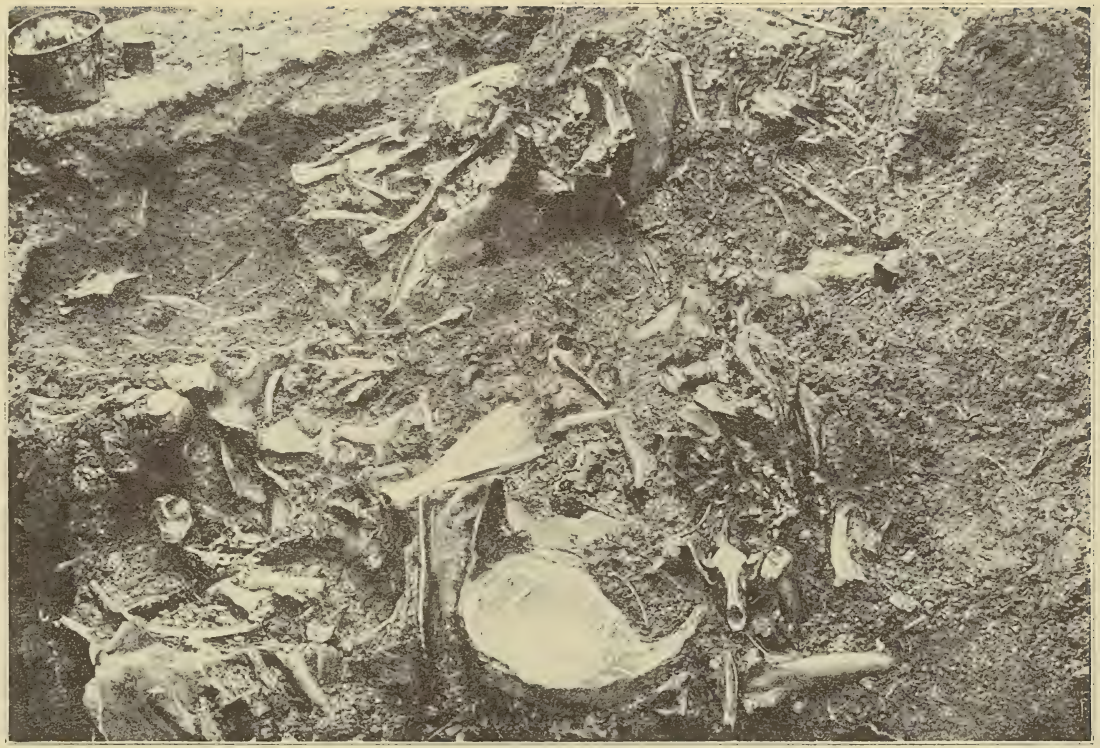
As the centuries passed, like a great procession streaming from surrounding hills and plains, the birds and beasts swept into the blackness of these pools. Here was gathered a multitude of witnesses, who through the "still lapse of ages" waited the time when in the unavoidable evidence of their reality they were to bring a living story of the past before us. They appear to-day not as formal revelation, but as clear evidence, which through this staying of the hand of destruction permits us to look into the living world of a past eon.

In the great numbers of kinds of beasts and birds entombed in the asphalt pools a large percentage are of types no longer living on any part of the earth. Many of these have their nearest relations in the life of still earlier ages. Such are the sabre-tooth, mastodon, ground-sloth and others. The elephant, camel, and horse, have close relatives living to-day on other continents. With these two groups are other species, as the coyote and puma, the rodents, many birds, and plants like oak and cypress that have intimate resemblance to species at home in California to-day. If the whole group of animals and plants from these pools could stand before us, the assemblage would be that of a foreign age or land, but among them would be many friends of our out-of-doors to-day. Here we face the reality of another world of life shown in many strange phases, and yet the beginning of the present reaches back to overlap that early time.

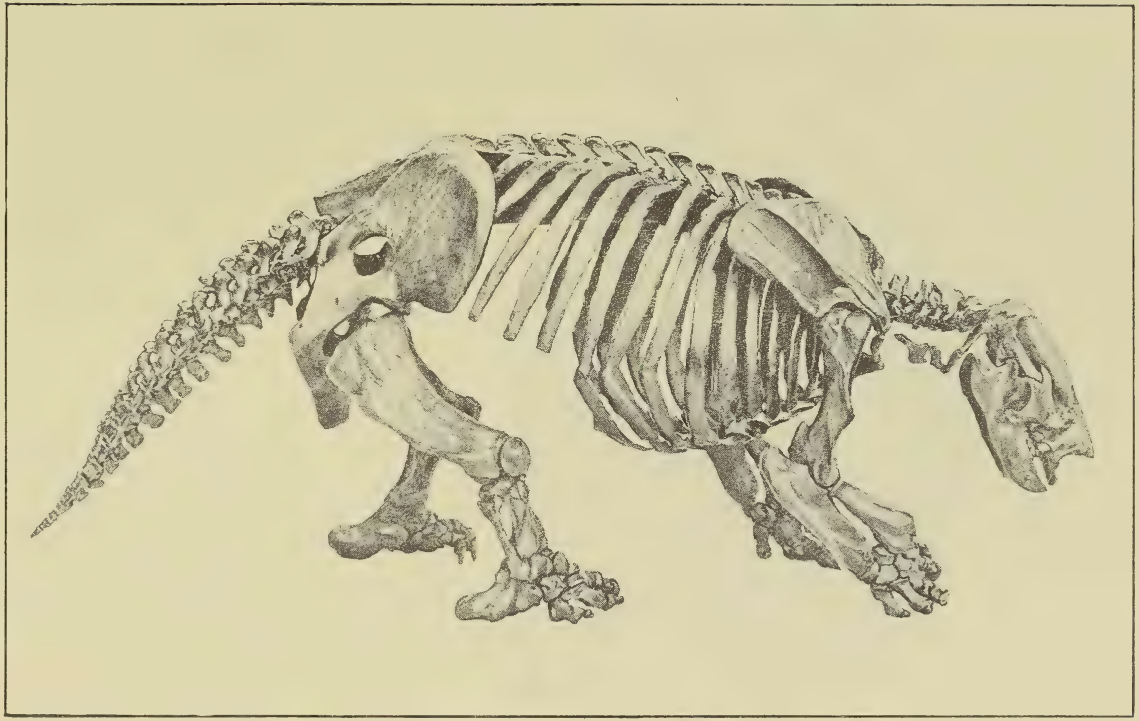


Courtesy of the Los Angeles Museum

Modern ground squirrel trapped in asphalt, Rancho La Brea

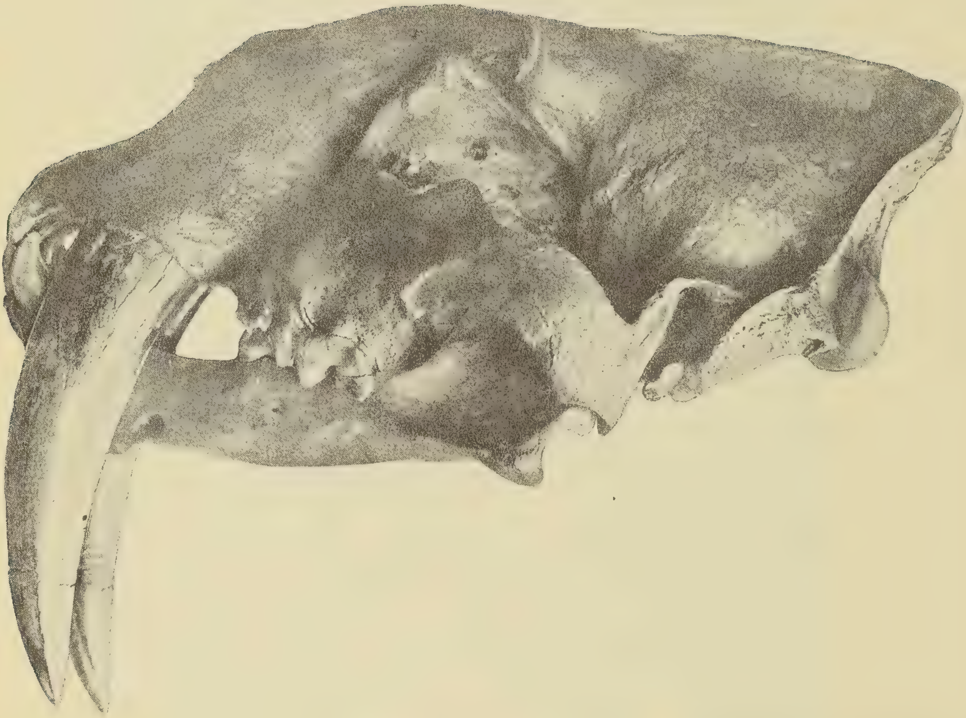


Undisturbed fossil remains of extinct animals in asphalt deposit, Rancho La Brea



Courtesy of the Los Angeles Museum

Skeleton of an extinct ground-sloth, Rancho La Brea



Courtesy of the Los Angeles Museum

Extinct sabre-tooth tiger, Rancho La Brea

THE STORY OF A LEAF

Illustrations from Photographs

It happens often that the greater things of nature, as in human life, are only imperfectly appreciated until in the light of a single circumstance suddenly they rise to overshadowing importance. So we read that when Elijah stood upon the mount before the Lord, it was not in the strong wind, nor yet in the earthquake or the fire, but through the "still small voice" that the Almighty was recognized.

On a recent journey to Columbia River Gorge I had the pleasure of revisiting a region familiar from many years of interest in the meaning of its history. As on other occasions, the bordering cliffs, with summits disappearing in mist and the river moving majestically below, made me see the canyon in all its strength and beauty. In the geologists' language, I read again the record of ancient floods of lava piled up to build a mountain in which later the river cut this gorge. But it remained for a fragment of a leaf, fluttering from its burial place in the foundations of the valley wall, to give through compelling vividness of its own reality the clearest expression of the story of creation which opened before me. The finding of this leaf continues always fresh in memory as one of those occasions when the past seems to open, and for the moment we look through to see the Builder at work.

It was on a stormy day in July that I passed through Columbia Gorge with a party of geologists engaged in study of the history of that fascinating region. Riding down over swinging curves of the highway we examined the rock formations which make the canyon-rim. The summit was built from edges of old lava flows. Below the lavas were thick layers of water-washed gravel, and boulders. Deeper in the gorge the gravels lay upon still greater lava flows, piled hundreds upon hundreds of feet to make the wall. Across

Scribner's Magazine, vol. 81, no. 2, pp. 130–134, February 1927. Republished with slight revisions as chap. III in *The Living Past*, pp. 41–54. New York: Charles Scribner's Sons, 1930.

the river these lava beds were seen extending widely under mountains and plains beyond.

As the panorama lengthened our wonder deepened. Rising two thousand feet around and above us were stony cliffs of what was once melted rock. Below, like a great ribbon-saw, the river was cutting its way with teeth of sand and gravel dragged upon its floor. We recognized the canyon as merely one stage in a process of shaping and moulding of the vast pile into which it had been cut.

Approaching the historic station of Bonneville, our party found the lower beds of lava along the highway resting upon a foundation of rocks that had formed the landscape over which these first flows were poured. This underlying formation consisted of layers of hardened sand, gravel, and mud. A member of the party who had made special study of the region stated that at this point the rocks beneath the lava contained buried in them remains of plants that flourished here before the time of the first lava flows.

It was where the highway skirts a steep bluff, before bending round the curve at Tanner Creek, that search was made for the locality reported by the specialist in history of plants. The cliff rose almost perpendicularly from the pavement. Its irregular face was marked by widely spaced bands of stratification representing difference in materials. In the first large exposure bordering the road, a log of petrified wood projected from rock which had once been the mud and sand that buried it. A few yards away the twisted stem of a dead tree of modern time hung over the cliff. The fringe of forest draping the bluff above was formed of fir, maple, willow, and dogwood. Near the fossil log a living alder clung to the face of the rock, and a sword-fern had fastened its roots in a softer stratum close by.

Rapid search revealed the locality reported to furnish remains of plants. A few strokes with a pick in the soft layer from which the sword-fern grew brought out fragments of rock covered with clean-cut impressions of leaves. There were maple, sweet gum, hickory, and oak, with numerous other kinds. The palæobotanist, who had spent many days collecting in this stratum, began to name the plants discovered. I interrupted to ask if he had obtained the Gingko, a beautiful tree originally known living only in groves about the temples of China and Japan, but found also as a fossil at localities spread widely over the northern half of the world. "Yes, I have found it, but only rarely," was the reply. "Oh," said a student standing near, "I have just seen an impression of a leaf." He ran to the cliff and brought a small slab. On one edge was a narrow imprint showing clear tracery of a leaf like a maidenhair fern, but duplicated only by the Gingko.

When the print appeared my mind went back to a tree of this strange type planted in the court of the Cosmos Club in Washington. I remembered sitting in the yard at lunch on a warm summer day and pulling down a leaf as reminder of the quest I wished to see for wild Gingkos in the primitive forests of Asia. I thought of the history of the tree as known to the palæobotanist—for millions of years widely spread over the northern hemisphere, and now only a slender residue remaining protected in the sacred forests.

Still looking at the slab, but with my thoughts in Washington, in China, and in the world of past ages, my youngest son brought me back to Columbia Gorge by remarking that he saw the leaf itself still in the rock. "No," I replied. "It is only the impression that remains. In these formations the leaf decays and disappears. Not even a film of coal is left from the carbon which it originally contained." "But the leaf is there," he said. Then, to prove the truth of my statement, taking the specimen, I pulled apart the layers on which the impression was made, and as they separated, clinging to the print, we saw a brown fragment of a leaf with one edge lifted and moving in the wind. The structure was that of a Gingko, time-bronzed and shrivelled—but a leaf, and not merely the trace of its form upon the rock.

My eyes turned to the bluff from which the fragment came. Beyond the layers of sand and mud in which the leaf had been entombed, rose cliffs of lava, stepping up and up to the rim of the gorge. I looked across the chasm the river had cut, and then saw again the remnant of the Gingko fluttering in the breeze. Since last the wind had stirred this fragile thing, a mountain had piled itself upon it. The floods of melted rock had sealed it in. And then the river, sawing for ages through the mass, had made easy its liberation by the hammer of a student seeking to know the truth about the past.

In careful wrappings the Gingko fragment from Columbia Gorge crossed the continent to tell still further details of its history through microscopic examination of its structure. At the laboratory in Washington it was lifted from the rock to which it adhered, and after careful preparation came to the table of the microscope. By its side lay a similar portion of a Gingko leaf from the tree in the court-yard of the Cosmos Club.

The expert first examined the modern leaf, noting the pattern of its cells. Then the ancient fragment took its place in the field of magnification. The lighter tint of the living leaf was replaced by brown of the specimen from beneath the lavas, but pattern of leaf and form of cell were as much alike as are two closely related ferns or oaks of to-day.

As he moved it about under the microscope, the specialist ran his eye rapidly over the surface of the ancient leaf-blade. He had hoped to find all details of structure present, but the guard cells bordering the breathing pores were not to be seen. He ventured the suggestion that "perhaps after all this never was a living, growing thing, but only an accidental resemblance to a leaf, or an incomplete experiment in creation." "Possibly," I replied, "you are looking at the wrong side of the leaf." The fragment was reversed. A few quick shifts followed, as the object was moved across the field of vision. Suddenly there was close examination of something that caught his eye. He changed the focus, and then motioned me to his seat at the microscope.

Looking down on the illuminated leaf, I saw dotting its surface characteristic pairs of cells which guard the pores through which plants obtain what they require from the air. It was clear that in this specimen, as in the green Gingko from the living tree near by, these little mouths had opened and closed through the rounds of daily life for a season. And then on a late summer day, as a golden leaf with its work completed, it had whirled down to the stream that buried it.

For a moment the fragment faded from clear focus, as I remembered the leaf where it lay beneath the wall of the canyon in layers of rock that had been mudwashed upon it ages before. And then the eye of my mind did what as yet no man-made instrument has accomplished. Through the assured reality of this leaf, as it was then and had been so long ago, a view was opened across the eons connecting present and past. In that sweep of vision it was not possible to avoid the panorama of history just as it had occurred.

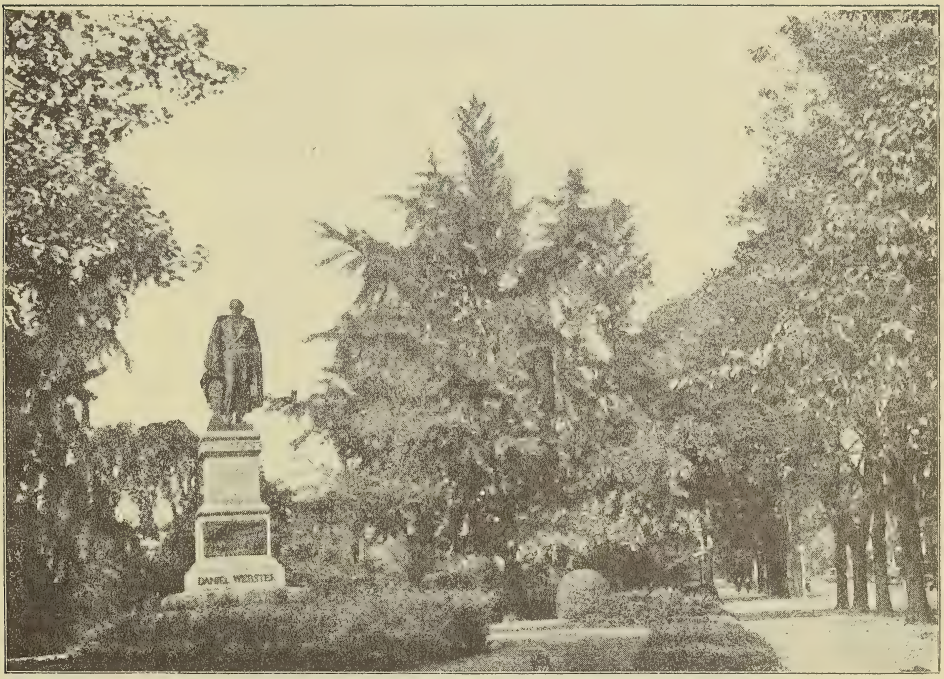
Glowing lavas crept out, flow on flow, through ages to build the mountain; and then a river began its work of fashioning the canyon. Suddenly my friend inquired: Had I seen the guard-cells? "Yes, and also travelled out across the continent, and back through time so far I might not guess the distance."

The cliffs in which the Gingko lay entombed in Columbia Gorge are included in Mount Hood National Forest. Some years ago a portion of the area was set aside by the Forest Service as Columbia Gorge Park. Within this region, by help of simple cards of description and direction, the traveller is assisted in his effort to know the lessons of the place more intimately. When next you visit the gorge, approaching Tanner Creek on the highway from the west, you will find a simple metal card marking the cliff in which the Gingko leaf was found, and in which others still rest. At the foot of the wall you will see a Gingko-tree planted from stock that grew about the temples in Japan. As it grows its branches will brush the rocks in which the ancient leaves are buried.

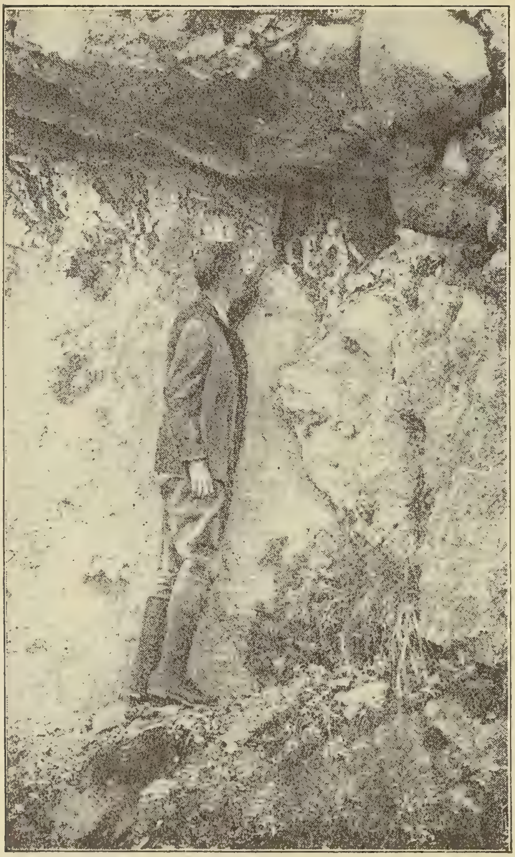
If you frequent the canyon you will find that no matter how often you follow the highway from Portland to the Columbia, there is always a thrill when the ridge above Crown Point is crossed and suddenly the gorge appears. It may be that to some this panorama expresses itself solely in terms of superficial form and beauty. Looking often over the valley, it has seemed to me that no one could view the picture without finding revealed something of that movement of creation of which it is the result. Commanding as are features of external beauty, evidences of the process of making portrayed are of such significance that details of the spectacle must be recognized as only incidents in a moving panorama. To know the whole story takes nothing from appreciation of form and feature as they appear at the moment. This knowledge only extends our vision. We come to realization that the elements of grandeur comprised in bulk and static strength have their present values because they are residual demonstrations of power exerted in a great work of construction.

To-day we begin to see through all nature the movement of great forces involved in the process of creation. As this panorama opens we glory in our growing power of comprehension. Then on a rare occasion, in an unexpected region, there appears a new expression of reality far transcending that built upon previous experience and imagination. This flash of understanding, with widening horizon, can come to each individual as veritable revelation. It may bring realization of unmeasured power bound in the atom, another universe beyond the stars, a new vista in the past, or an explanation of some baffling phase in human life.

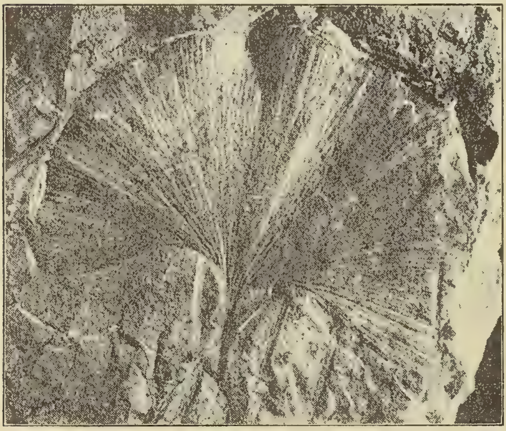
We may stand often, as it were upon the mountain, with the elements spreading their power before us, and yet miss the gentler message that makes it possible to see behind the face of nature and read the movement of its mind. It was under such circumstances that the fragment of a leaf—meaningless, excepting as it helped support a cliff above—opened the doors upon a living past. There fire, earthquake, and the flowing power that cleft the mountain, each was seen to have its part in building order and beauty into the world in which our lot is cast.



A living Gingko-tree at Scott Circle, Washington, D. C. Daniel Webster Monument to the left



Locality at which the "fragment" of a Gingko leaf was found in Columbia Gorge



From a photograph by Dr. R. W. Chaney

Impression of a Gingko leaf on the rock at locality where the "fragment of a leaf" was found in Columbia Gorge

FOREST WINDOWS

The President of the Carnegie Institution of Washington reveals a quality of poetic beauty in his writing. Weaving his scientific knowledge into the pattern of an essay upon the significance of trees, Dr. Merriam has approached both beauty and truth. [Editor's Note]

I

Across the valley from my childhood home rose a wooded hill from which the timber had been partly felled. Seen over open pastures the margin of the forest appeared always as a dark, impenetrable wall. The woods lay beyond reach of my journeyings and gradually came to be recognized as a place of continuous night. Often at evening we heard wolves howling on the hill. Other wild things were said to make their homes there. So this mysterious region peopled itself and came to be an established feature in the world as I knew it.

I recall the first visit to the timber—riding up to a wall of trees, into which to my surprise it was possible to see; but beyond, in the depths of the wood, there was still dimness and a land not fully penetrated.

Whoever looks into a forest, whether through eyes of the inexperienced or untutored mind, or with penetrating keenness of enlightenment, finds its windows framing pictures in which the shadowy background presents a challenge to imagination. The trees bordering its vistas impart their strength and beauty even to the darkening areas beyond. With this frame and setting the mystery of the forest has always been a stimulus to inquiry and answer. The groves have ever been temples, because through them we have turned toward contemplation of undefined sources of being and power represented there in qualities of living things.

II

As years pass, the challenge of the unknown continues as it first appeared to me behind the dark front of a wood. The openings

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into this attractive region have been of many kinds, often through the trees themselves as represented in problems of their beauty, their life, or of their evolution through the ages. So it came that with a group of friends I rode to see a forest wall reported to have mystery and charm unique among living works of creation.

A morning sun brought out all the brilliance of a landscape in the north coast region of California. The rugged hills through which we passed were mainly wooded. Dark masses of fir gave place now and then to redwood, or a patch of ripened grass-land rested like a golden brooch in deep green velvet of the forest. Suddenly we swung from the highway, dropping down a steep slope into primeval redwood timber. The car quieted as its wheels rolled over the leafy carpet. The road soon ended in a trail, and the party proceeded on foot.

As we advanced, the arches of foliage narrowed above us and shade deepened into twilight. Between close-set trunks one looked through windows framed in shadow, often darkening till all detail disappeared. Here and there behind these openings was a distant aisle in which faint touches of sun upon the shaft of a young tree brought out its red-brown glow. Through other reaches vision was lost in failing light. Like pillars of a temple, the giant columns spaced themselves with mutual support, producing unity and not mere symmetry. The men of the company, who all their lives had known great forests, bared their heads in this presence. Ponderous strength, an almost infinite variety in expression of light and shade and color, and a perspective with marvellously changing depth composed a scene such as canvas has yet to receive.

But woven through this picture was an element which eludes the imagery of art. The sense of time made itself felt as it can but rarely be experienced. While ancient castles may tell us of other ages in contrasts of their seemingly fantastic architecture, living trees like these connect us as by hand-touch with all the centuries they have known. The time they represent is not merely an unrelated, severed past; it is something upon which the present rests, and from which living currents still seem to move.

We realized that the mysterious influence of this grove arose not alone from magnitude, or from beauty of light filling deep spaces. It was as if in these trees the flow of years were held in eddies, and one saw together past and present. The element of time pervaded the forest with an influence more subtle than light, but that to the mind was not less real.

III

Among the living redwoods, as in few places, one's thought turns irresistibly to focus on the meaning of the past in its relation to present and future. Considered in the setting of their history, these trees open to us one of the most fascinating chapters in the story of life.

Within the belt of redwood forest in northern California I visited recently a place where in the solid rock, forming commanding hills, there lie remains of many massive trees differing little, if at all, from redwoods growing on slopes nearby. They are now trees of stone, but in all details of form and structure, even to microscopic minutiæ of the cells composing them, they are redwoods. In clay-like layers of the rock in which these trunks are buried, imprints of leaves are found such as are made by foliage of redwood-trees buried in muddy borders of streams to-day.

One imposing column, known as the "Monarch of the Forest," has been followed back by excavation, where its broken end projected from the hillside, until almost one hundred feet of its length is visible in a tunnel extending into the rock. The log, six to eight feet in diameter, still lies embedded in its stony matrix. In the roof of the cavern, undisturbed strata of the material which buried it arch completely over this splendid pillar.

As I stood in the excavation looking out along the great tree, a tourist engaged me in conversation. Asked what impressed him most in viewing this specimen, he replied: "The fact that there can be no doubt of its having lain buried for ages in this rock which covers it. It surely was once a tree that stood up and faced the sun, and"—pointing with his foot to a deep hole in its side—"I suppose that birds and beasts of long ago nested in its trunk."

One stands outside the tunnel and looks over the hill above. The rock that forms the slope seems a huge bulk of material piled upon the trees beneath, but it is only the remnant of a greater mass that came largely from ancient volcanic eruptions—perhaps from the region of Mount St. Helena near by. The thickness of ashes and mud which formed the original deposit we do not know, but since they hardened to consistency of stone the flow of streams has been for ages carving the face of this land into its present form.

Through all the time this shaping of the landscape was under way the prostrate "Monarch" lay in quiet deeper than that of the forest in which it once grew. The noise of battling elements and of warring creatures above did not reach it. Only now and then there came a trembling of rocks around it or the rumble of a swiftly passing earthquake, as the foundations of the hills were shaken by movement of the uneasy earth. And then the world of light returned, stream and wind flowed over it, living forests gathered round it, birds and beasts climbed again along its frame, and finally man came to see it—both as it is and as it was.

IV

The redwoods existing to-day are surviving remnants of a splendid race that was many million years in developing to its present majestic stature. They are rare examples of a group spread widely over the world through long periods, and of which just sufficient is carried over to the age of man to tell us the contribution it has made to life of the earth.

In northern California, where these forests reach their highest development, they extend over a country of deep valleys and bold hills or mountains rising to an elevation of several thousand feet. The features of the landscape are determined in part by variation in the geological formations from which they have been cut. A considerable portion of the area in which the finest redwoods grow is underlain by a series of sand and clay strata thousands of feet thick. Embedded in these hardened sands and muds are remains of animals and plants that lived in the region at the time the layers were being formed. Among these relics are the stems of redwoods.

At the little town of Garberville, where I spent many pleasant days in study of the country, strata of this formation at least a half-mile in thickness are exposed by the south fork of Eel River. In places where the stream is cutting its bed in solid rock the section interprets itself so clearly that no one who sees can fail to understand.

I asked my friend Monroe, age eleven, whether he had ever found clam-shells or remains of other animals in the cliff where the river impinges on a high bluff near the town. He took me over the precipitous wall to a point where sea-shells were embedded in solid sandstone. Near by was a large fossil vertebra with stony matrix still clinging to it, and from the solid face of the rock above we dug a whale rib.

A short distance below us the swift stream washed over lime-cemented reefs of sandstone filled with perfectly preserved shells, including scallops, razor-clams, and many other kinds. These remnants of ancient deposits with the remains they contain once spread over the bed of the ocean. They had been heaved and bent until now their steeply tilted and eroded fragments stand high above the sea. On the slope near by stood a grove of redwoods, a surviving remnant of forests whose entombed remains lie in the hills upon which they grow.

V

As I stood with my friends looking into the forest, which we had come so far to see, in swift panorama the history of the redwood and of its surroundings as I knew them passed before me stage after stage from the remote past.

The distant age of reptiles with its weird population, the dinosaurs and all their kin, presented a picture of the world with face that was strange as to sea and land and life upon it. Though plants with what we know commonly as flowers were just beginning to spread their mantle of fragrance over the earth, the redwood tribe was already widely distributed. The coming aristocracy of hairy animals, with brains that dominated their bodies, was slowly learning to outwit the dinosaurs and to protect its brood.

Then came the age of mammals, when the alert, hairy creatures that escaped the reptiles of earlier days ruled the world with both brawn and growing brain. I thought of the period within that time when the immediate spot on which we stood had lain beneath an ocean whose waves swept smoothly over it or crashed upon a near-by shore. From hills on which grew trees like those about us, a wash of sand and clay was then flowing to the sea, forming the mass that was to be raised up and moulded into the landscape of to-day.

Excepting for details, the living redwood grove on which we looked was like those that flourished in past ages. The under-growth of spreading ferns could trace its relatives to even earlier time, and the zone of shadow to which they clung was the continuation of a moving region of shade that reached back not for epochs simply but for eons.

As on a journey when it is to-day New York, yesterday Washington, to-morrow Boston, in speaking suddenly you hesitate a moment to be certain whether it is Washington, New York, or Boston in which you find youself, so in this swift flight of thought I almost questioned whether it might not be a wood of early time that spread itself before me. Walking toward the deeper shadows, which obscured such features as may distinguish vegetation of the present from that of the past, it seemed almost that one should search among the ferns for the moving neck of a dinosaur, or in branches of the trees for slender wings of a flying reptile.

My associates were interested in the relation of this little world of life in which we stood to the geological past out of which it had grown. They asked why I might not expect to see a descendant of dinosaurs among trees that have come down to us with such close resemblance to those of ancient times.

I framed words of a reply, to the effect that probably animals change more rapidly than plants, as their structure is more complex and responds more quickly to variation of its surroundings. As I began to speak, looking with all the others into the narrow lane beyond, I saw clinging to the shaft of a great redwood an uncanny shape with lifted head, and tail that wrapped about the tree. Instead of the carefully stated philosophic answer, I replied: "I have never seen a dinosaur alive—unless I see one now."

The grotesque form upon the tree was only a "burl," an irregular growth frequently developed on the redwood, and treasured for the rare beauty of its wood. But often as I see them, hanging like ancient monsters where shadows give them changing form and countenance, my thought leaps over intervening ages to a time when about the ancestral redwood groves there strayed fantastic reptile generations, that in their day were lords of all creation.

With whatever turn of fancy one views this forest, it must always be recognized as a living link in an epic of history. No one who knows the outlines of its story can look down the long vistas, between gigantic columns, with the mystery of their changing shadows beyond, without feeling that he has seen through a window into the deeper reaches of time, and has come to fuller understanding of the stream of life as it is followed through the years.

VI

The wilderness of the inner forest lured us to explore its depths. In a jungle of brakes and sword-ferns we clambered over stems of redwoods piled in crisscross. Magnificent even in their dissolution the prostrate giants, lying rank on rank, stretched back the generations of this wood to centuries not reached by its most ancient living trees. Standing on a fallen column, out of whose body grew another redwood, we first took breath and looked about.

Among these deeper shades, in turning toward the world outside, for the first time we saw the narrowing vistas ending not in shadow but in light. It was the flood of radiance sweeping against the vault above, penetrating here and there to give its living touch, that dominated the region beyond.

Looking through crowded tree-tops, there was a glory in the forest that otherwise might have remained unknown. The summits lifted themselves to heights at which the voice of the wind in their branches was hushed by distance, and the delicacy of the topmost fronds seemed refined to lacelike texture. Moving gently, they touched across the openings, producing continuous variation of the light that streamed or filtered in. Beyond was the infinitely changing sky, a glowing sapphire through interlocking branches at midday; or with indescribably delicate tints if one may see it when level rays of morning or evening sun sweep over.

Standing in this field of shadow, among living relics of distant ages, we seemed in looking out to turn from the clear story of a moving past to see the future rising from it through the miracle of never-failing light—the light that in unnumbered eons had poured down to mingle with the clouds of verdure, and build itself into the unfolding life and beauty of the forest.

AN ABYSS IN TIME

In any effort to interpret the story of life as it runs through the ages it is important to have a background of time against which to project the movement of events. If one attempts to form such a conception, it is found commonly that the materials from which it might be derived are difficult to assemble. While there are many aspects of nature in which succession, relative position, and movement illustrate the basic principles of history, it happens rarely that we see the elements of a series of incidents so situated that the evidence of continuity is clearly expressed.

The almost incomprehensible reaches of astronomy give us measures of space and time which, through their relation to each other, present a stupendous picture. But in general, in this field, there are obstacles in the way of obtaining observational illustration of actual historic sequences. It is the object or the light at a given place and at a particular moment that we see, and not the complete picture of development.

In human history one may observe, as it were coincidently, the steps in growth of a great cathedral which has been under construction through many centuries. Or in an archæological excavation we see the wreckage of successive civilizations piled in layers, one upon another, in such manner as to present the story of change and movement transmuted into a measure of time.

As the geologist views still greater series of layers or strata he sees their parts, or the long succession of events which they represent, as portions of a single picture. Even where remains of the record are only fragmentary, his trained eye arranges them in the order of their occurrence. To those without this experience, a similar appreciation of the meaning of geological time and its content may be obtained in certain exceptional glimpses of the process of earth-building. The Grand Canyon of the Colorado is one such spectacle which appears to impress the meaning of its story upon all human kind.

The Living Past, chap. V, pp. 73–92. New York: Charles Scribner's Sons, 1930.

Among factors determining the effect upon us in viewing the Colorado Canyon, the conditions controlling first sight of the region have much importance.—Commonly one comes suddenly upon the abyss. By whatever road the journey is made, it is almost the universal experience of the visitor that he travels long across what seems an almost interminable stony plain. Though an occasional mountain peak or butte rises to break the even surface, the architecture of the earth expresses itself as a broad sweeping structure formed from unmoulded masses of the level crust. The peculiar fragrance of the wilderness, and its strange quiet, lull him into acceptance of the panorama as a continuing stream.—And then at the rim of the Canyon, with startling abruptness, the apparently interminable picture of meadow, and forest, and broad lands comes to an end, as if the materials of creation had been lacking or some great change had taken place in the plan of nature.

Whatever else results from sudden contact with the spectacle of the Canyon, there should be no doubt concerning the deep impression made by the great magnitudes in height and depth and bulk, as by its changing garments of light that are never twice the same. It may be that for some the influence ends with this imprint. The vast majority seem moved by something great beyond definition, and rise to unconscious appreciation of the fact that what lies before them represents more than just the face of the world as it might have been left from an initial act of creation.

On the deeply notched and sculptured walls, with buttresses and pinnacles reaching out to distant buttes, one recognizes in the varicolored layers a continuity of structure which appears to extend to the farther rim. The fracturing and splitting of minor features of the cliffs near by seem only an indication of processes involved in production of the marvellous architecture. Whatever be the influence that made these forms, the work accomplished is clearly the result of building or moulding in nature, and not a thing remaining as it were from the beginning. Regardless of what the point of view of the visitor may have been, scientist, philosopher, and the merely curious observer, all inevitably interpret what they see in terms of the idea so often stated in words of the cowboy, who is said, many years ago, to have ridden without previous knowledge or warning to the brink. His exclamation, "My God, something has happened here!" reflects the universal sense of recognition and appreciation of power and movement in the making of the Canyon.

However far ingenuity and the imagination of the beholder may go in developing an explanation of construction or excavation at the gorge, one may not expect the untrained observer immediately to develop a theory accounting for so large a work. But the mere appreciation of this greatness, and of the evidence that something has been framed by power beyond our clear comprehension, represents an influence of much significance.

Behind the features which express size and beauty, the interest of observers is challenged by questions concerning the making of the gorge and of its walls. Whether for the investigator, or only an interested observer, the only verifiable answer to these inquiries comes from examination of the Canyon itself.—One rides down over winding trails to view the river which forms its floor. The turbulent stream is found laden with débris ranging from discoloring mud to sand and gravel moving in its swifter current. Along the bank lie multitudes of worn pebbles and boulders, tools for the heavy work in grinding out obstructions on its bed. Whoever feels the throb of this plunging power as it tears its way, and sees the wreckage which it sweeps along, has found at least a portion of the answer to questions regarding the instrument which produced the Canyon. Fragments of rock from the walls heaped in the bars, the continuous torrent of muddy water passing by, the surging might of the stream, and the strength of it all multiplied by time, suffice to account for the major work as the river cuts its channel across the great plateau.

The story of the river and its work in excavation of the Canyon suggests in another phase an answer to the query as to how the walls were built.—The engineering problem of the projected Boulder Dam across the Colorado River concerns itself not alone with holding behind a barrier the water that is needed. There is reckoning also with the burden of accumulating mud that would drop as a slowly thickening mantle to diminish the cubic space designed for water storage. Information as to what could happen in accumulation of débris at the dam is given in the content of the river as one sees it pass, as also in the load which it delivers when it enters the sea at the end of its journey. Visualized in terms of result rather than as mathematical calculation, one finds at the mouth of the

Colorado a wide plain extending itself into the sea. The mud brought down spreads itself now here, now there, as currents shift. As a great developing feature in the landscape it presents a picture of the river as a builder.

We turn to the trail leading from river to brim. As the mule plods slowly up, the unfolding panorama shows us the varying brilliance of color represented by changing types of rocks. Here are spread mounds of gravel cemented into adamantine hardness. There lies a wide stratum of sandstone once a mantle of sand. Beyond is a layer of hardened mud, with tint like the Colorado's water. In the mud are prints of a fern, and a tree washed into the accumulating layers as they formed. There in the sand are shells that belong on a seashore. Near them are tracks of a crablike creature, made as it picked its way over the débris. And above, on the summit of the wall, is a huge deposit of limestone bearing in its mass a multitude of shells and corals whose natural habitat is in the waters of a warm, clear ocean.

The Colorado shows us how a river may drop its load on the border of a sea to form a new feature in the endless remodelling of the earth's surface. The walls through which the river flows exhibit the result of a vast work of building of this type. They are in large part mud and sand and gravel moved by rivers or pounded by the sea through a great succession of ages.

However long a time the process of cutting the present Grand Canyon may have required, its contribution to the construction of new formations may be only a minor unit in the earth's crust. On the other hand, the pile of layers forming the walls of the Canyon is spread over a broadly extended area. Far to the north and south one recognizes these formations by all their characters of color, texture, and mode of erosion. The geologist actually traces the strata from one region to another. This vast work of accumulation, as known by all available means of measurement, seems to have occupied a time ranging beyond the possibilities of our full appreciation. In spite of rigorous examination of the methods used in determining the length of this period, the estimated measure of years required to pile up the materials which form the Canyon wall reaches into the hundreds of millions.

But the records of history presented by the Canyon region are expressed only in part through the cutting of the present gorge, and in the building of the larger units of the walls. The processes of erosion and construction are shown on a stupendous scale in other ways.

If one stands on a high point near the margin of the Canyon and looks out over the pine-clad plateau, here and there isolated peaks are seen to rise above the general level. Such are Red Butte and Cedar Mountain. These two are remnants of horizontal layers of consolidated mud, sand, and gravel resting upon the uppermost strata of the Canyon rim. The same formations appear in the cliffs bordering this plateau surface far to the north. In whatever direction one goes, evidence multiplies that these deposits once extended over a wide area now traversed by the Canyon. Running water removed this mantle of rock, which was approximately as thick as the present Canyon wall is high. This occurred mainly before the Colorado sliced through the lower and older layers to make the relatively minor feature which is the Grand Canyon of to-day.

Still more impressive are the records of great events in earth history told by the lower and older portions of the Canyon cliffs.—Deep in the valley, immediately below the place from which the river is commonly viewed at El Tovar, the course of the Colorado lies in a narrow, so-called Inner Gorge. When one visits this lowest section, the rocks are found upturned and shattered in innumerable ways. The type of movement which has affected them is known by geologists to be characteristic of the greatly disturbed and folded masses which form the roots of mountains.—But the mountains of which these rocks are considered to be the roots are no longer there.

For a great distance along the lower Canyon one sees a wide stretch of horizontal layers of consolidated sand and gravel resting upon an approximately even floor cut across the tilted and broken rocks of the Inner Gorge. These upper strata, known as the Cambrian, are not a part of the lower series. They differ from it radically in texture and structure, and are not appreciably bent or crushed. They have seen little of disturbance since the days when each sand grain or pebble in turn ceased its wanderings to settle quietly into the place it was to occupy in the building of this great structure. As one rests inquiring eyes upon the smooth roundness of the larger fragments, and realizes that rushing waters ground them to varying grades of size and form, it is clear why the mountains are no longer there.—The ancient upheaval which altered the earth's surface in this region sharpened the movement and effect of the streams passing over it. Time and the elements transformed the mountains into flowing gravel, sand, and silt. Possibly some worked-over remnant of that mass has, in its moving to and fro, come to rest upon the remaining roots of the uplifted area. Perhaps in the new rôle, as accumulating wash from a disintegrating land, it was mainly carried to some remote area on the border of a then-existing sea.

The line that separates the ancient rocks of the Inner Gorge from the horizontal sands above occupies no space on the Canyon wall, but it presents a record of one of the most extended periods in history of the earth. The events in this region between the date when the older series of rocks was formed and the years when the first thin layers of the Cambrian sand and gravel were laid upon its eroded surface, represent as much or more of time—of building and of tearing down—as is recorded in the whole spectacular story of the Canyon shown in the walls above this line of demarcation.

Geologists tell us that the older rocks which form the Inner Gorge could have acquired their present characters only under a covering layer greater—perhaps several times thicker—than the whole mass of strata which now rests upon them. The shattering, the alteration of mineralogical composition, and the filling of wide fissures with dikes of granite-like material, could have developed only under conditions of pressure and heat, requiring an overlying mantle of rock many thousands of feet in thickness. This great covering mass was furnished by the elevated region that has washed away. But the lifting up of the mountains and their subsequent removal represent only a part of the series of events that intervened before the sandy layers of the Cambrian came into their present position.

Exposed in limited areas at several points in the lower part of the Canyon, remnants of another ancient series of strata known as the Algonkian lie between the older rocks of the Inner Gorge and the wide-spread Cambrian. They were deposited mainly as gravel, sand, and mud upon the eroded surface of the lower rocks of the Inner Gorge. This occurred after the early mountains vanished, and before the Cambrian layers had appeared. The mass of material was not less than twelve thousand feet thick, or more than twice the height of the pile of strata in which the present Canyon is cut. Its accumulation continued through long ages, after which all but these fragments was swept away. So, when the broadly extended sand deposits of the Cambrian came to rest upon the worn surface of the older formation of the Inner Gorge, they covered and protected also this record of an enormously extended age.

Impressive as is the story of the Grand Canyon considered as a tremendous excavation in the earth's surface, we may not escape the conclusion that a much greater activity than the shaping of the Canyon itself is represented in the erosion which removed the widespread mantle of strata that covered the upper plateau region into which the Grand Canyon has since been cut. We know also that the mere line above the shattered rocks of the Inner Gorge carries a record of earth-building in which the elements of magnitude and power are greater than the combined work of making the present gorge and the stripping of the broad plateau above.

The influence upon every visitor who stands on the brink of the Canyon, whether it be mainly in terms of size and beauty, or only in framing the questions "how?" and "why?" means an opening of the mind to new and greater personal experience. Appreciation of what lies beyond the most obvious aspects of the story may be slight, but those who search for an interpretation receive at least a faint suggestion of the "something that has happened."—The physical abyss impresses with its majesty and power. The matchless architecture, the colors spread in unimagined ways, the changing hues of atmosphere and sky and shadow, all bring unfailing joy.—With no less vital reality, the vision of time presents itself like the opening of a door upon the past. Perhaps even more striking than the contrast of physical grandeur of the Gorge with the gullies and canyons of our previous acquaintance, is the comparison of this great chasm of ages with the measure of passing years as we have fathomed them.

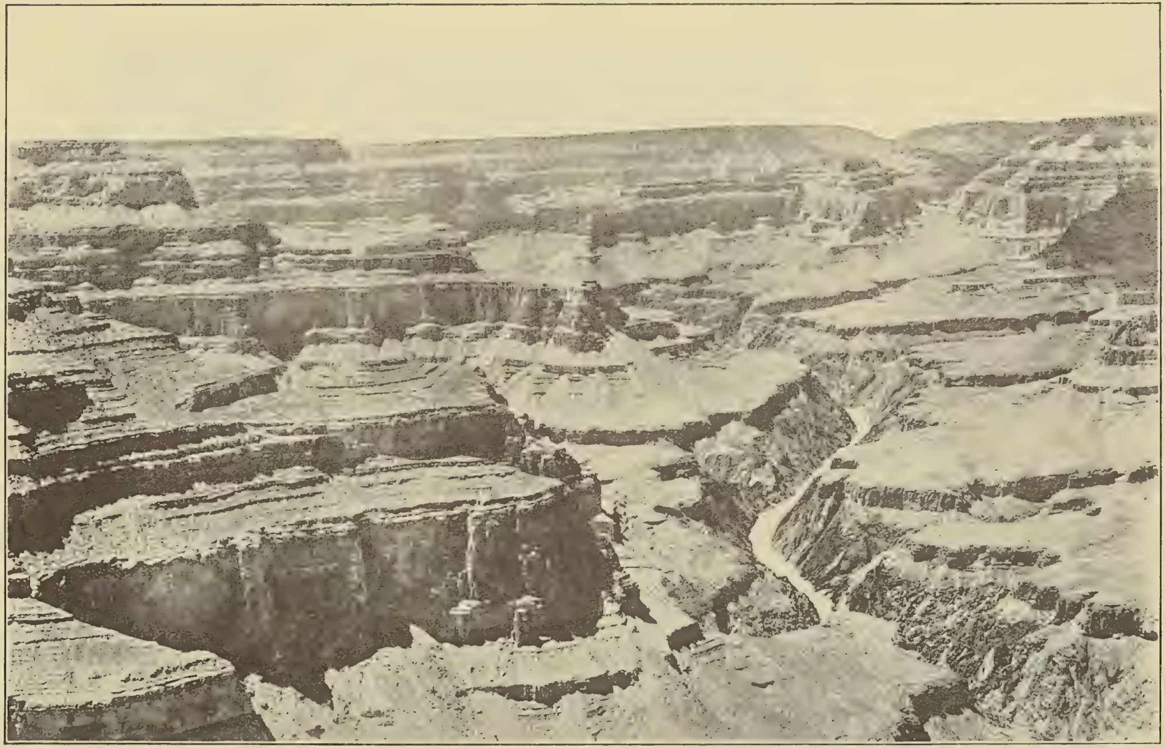
For those who go down into the Canyon to set their feet upon the strands of early time, or to lift with reverent fingers the trace of a fern that for years in untold millions has rested on the bank, there are places where history not merely reveals itself, but for every one seems waiting to tell its story. With a sense of reality like that of the present, in standing before these ancient links in the record of the earth, we are conscious of the streaming waters that rattled and pounded the heaps of worn and battered rocks, or of lapping waves as they spread the sand upon beaches where crawling things marked the rhythm of their pace upon the floor.—And the whole long panorama represented in the Canyon wall becomes a thing of life.

But the meaning of it all is not comprised in the startling reality of the many episodes in history that one encounters, nor yet in the truth that the sequence in which we find them is the order of changes in nature. When from some commanding point one looks out over the spectacle, not merely is there apparent the true significance of each of a multitude of incidents in order, but the relation of these differing aspects of the world to each other translates them into an expression of activity extending through time. One sees the mechanism of nature and of history as if with all its parts in operation, and compasses the great complex in a single sweep of vision.

As this abyss of time cuts down across the ages, it presents in clear perspective of one great picture the reality, the sequence, and the movement in a vast tide of events. The beginnings do not appear, but upon the high walls enough is written to illustrate the processes of change, and to show us also that the end is not in view.

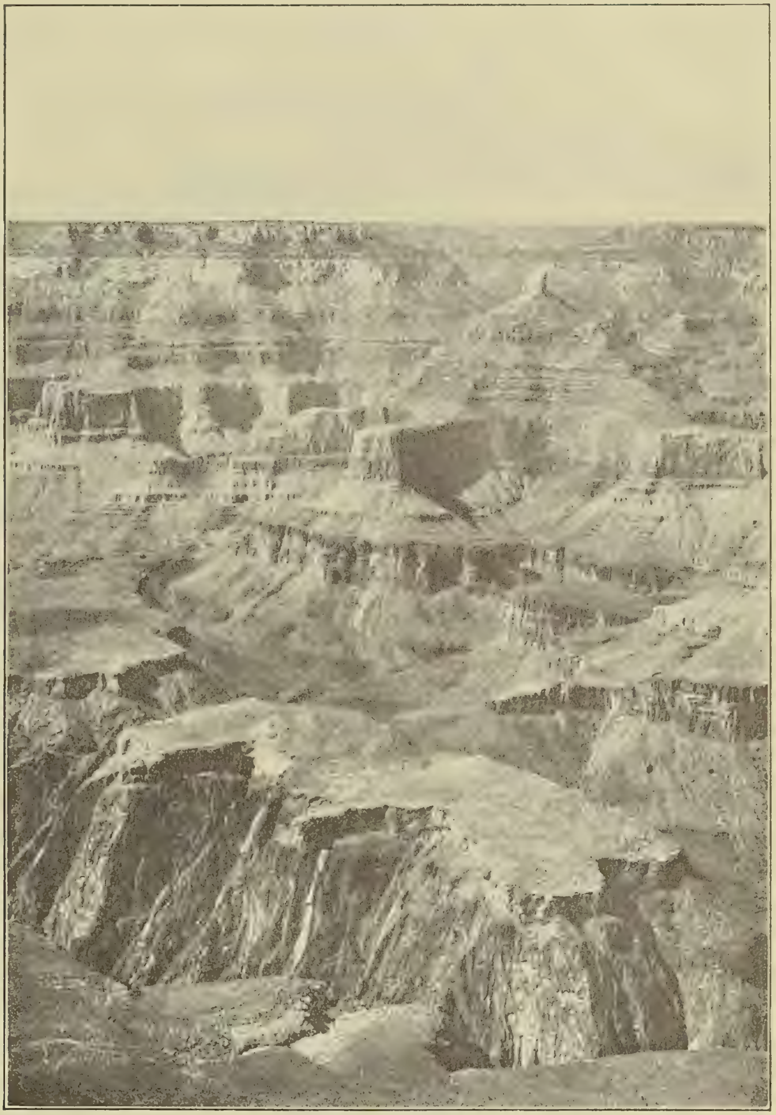
Courtesy of the National Park Service

The river in the Grand Canyon, with "fragments of rock from the walls heaped in the bars".



Courtesy of the National Park Service

General view of the Grand Canyon formations, including Inner Gorge with horizontal Cambrian sand layers resting upon the oldest rocks.



Courtesy of Dr. F. E. Wright

Section of Grand Canyon with Inner Gorge in the foreground, showing horizontal Cambrian sands resting upon the shattered older rocks exhibiting vertical fissures filled with granite-like material.

ANCIENT FOOTPRINTS IN THE GRAND CANYON

Illustrations from Photographs

ALTHOUGH our libraries and museums furnish a wealth of evidence regarding the meaning of history, no source of information can ever equal in interest actual original records when we find them undisturbed since the time of their making. So it is that the arrow-point which a boy discovers deep in the body of a tree makes real to him the picture of frontier days described by his grandfather. Or a finger-print in cement of an ancient wall causes our vision to flash back across the centuries and brings the builder before us as an unavoidable reality. The thrill that comes from examination of such first-hand evidence serves as does no other kind of experience to lay solid foundations for education and belief.

It was while searching for materials of value in a special study of ancient life that the writer first had opportunity to see an original record of surpassing interest in the form of a trail crossing the south wall of the Grand Canyon. The finding of this trail was described by my guide as we stood on the Canyon rim with the panorama of the gorge open before us.

As the story ran, the caretaker on Hermit Trail was clearing away rock from the lower end of the White Zigzag, a thousand feet below the rim of the Grand Canyon. Lifting the slabs of sandstone he noticed that they were smooth like stones of a pavement. As he uncovered a long block in widening the path, he was thinking: "Here is one which no foot of man or brute ever touched." Then his eye caught the print of a little clawed foot with toe-marks thrust deep into the sand—and then another, and another, and another, as the tracks, evenly spaced, reached across the slab. The last showed only the tip of a heel where the overlying rock bordered the path. It occurred to him that the toes of this foot might be

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under the rock. Looking more closely, his eyes stepped again from print to print until they rested on the heel pointing beneath the cliff. Seizing his pick, he carefully pried up the slab above. The heel stretched forward into imprints of toes, and just beyond it another heel marked a continuing trail leading under the wall.

Leaning against his pick-handle, the trail-maker looked up at the cliff—across the thousand feet of rock, layer upon layer, that built the wall above. He turned and looked out toward the Canyon, cut nearly a mile into the earth since the topmost rock stratum was finished, and said to himself: "It was sure feet that made them tracks, but it's a long while since they passed this way."

Mike and Bert, who had told me this story, promised to point out the spot where the trail with ancient footprints marked in solid rock crossed the White Zigzag on the Canyon wall. Next morning found us dropping over the rim at Hermit Rest. Passing down into the gorge, we crossed a great thickness of limestone layers, filled in places with shells of animals that lived in the sea in which these deposits were formed and left their lime-bearing remains to make a part of the accumulating mass. Lower in the Canyon the rocks changed to sandstone, spread originally as even sand layers but hardened during the lapse of ages to plates and slabs of stone now called the Coconino sands. Where strata of different texture were separated we could see the surface of each bed of sand exactly as it was before succeeding deposits were laid upon it.

Resting on the way for a moment, in the shade of a projecting rock, we were talking of the object of our excursion when Bert pointed to the footprints of a wildcat which had followed the path some hours before us. Then we hurried on down the slope—following the trail which the big cat had marked in the dust.

In crossing the strata of the lower Zigzag, every exposed surface of ancient sand layers was inspected with care until Bert, somewhat in advance of other members of the party, waved his arms in indication of success in his search. We hurried to the spot. At this point the trail was cut into the rock. Below it was a mass of loose blocks, partly formed by natural disintegration of the cliff and partly torn out in cutting the path. On the upper side, undisturbed sandstone was exposed in a succession of thin layers readily pulled apart.

Bert pointed to a wide slab extending into the wall. Bending eagerly to examine it, we saw on the fine sand of its surface marks of feet walking from the dust-sprinkled floor of the trail over the face of the rock and disappearing beneath the layers above. The four feet had been set down daintily and yet firmly—the sharp toes cut deeply into the sand. The spread or straddle of the double row of footprints indicated limbs set wide apart, as in salamander-like forms whose bones are found in rocks of the age in which the Coconino sand was deposited. The tracks were not those of any animal known in the life of Arizona to-day, but their clear imprint, and the regular spacing of footsteps crossing the surface, left no room for doubt that we looked upon the trail of a creature that moved alive over this sand.

Looking back to the spot where the slab with ancient footprints crossed the path over which we had come, I noticed the touch of a wildcat's foot showing faintly in the dust. Kneeling, I wiped the rock with my hand, and then with closed eyes blew away all remaining particles. When the air cleared, I looked again. There, where the cat had left its imprint in a film of dust a few hours earlier, were tracks of little feet marked on the sand, now hardened to stone, and between them in the same rock was the sharp cut of a mule shoe.

No one of us had seen the cat quietly tiptoe by in early morning, nor had we watched the mule with its tourist passenger tramp circumspectly down the slope, but we needed no further evidence to assure us of their recent passing. We knew also that even the venerable cliffs rising around us could not have viewed the making of footprints in the Coconino sand. We realized that the Canyon with all its majestic expression of antiquity and stability must have been still in the future of creation when the seconds and minutes of that early time were marked off by rhythmic movement of the feet which made this earlier track. And yet, as we looked upon the two records, the prints on ancient sands, preserved through time beyond human understanding, were not less real than were the traces of feet of cat and mule made in the morning of the day on which we found them.

Here was the crossing of two trails. Each was clear and unmistakable; one made that day, the other held unchanged as by a miracle from time so remote that we could only vaguely appreciate the magnitude of intervening ages.

Down into the gulf of the Canyon we had followed the tracks of wildcat and mule zigzagging over uncovered edges of strata piled upon the surface marked by the older trail. Each successive layer of the multitude traversed contained a record of events that marked years leading back to the day of the Coconino creature. Then, as we halted where this modern trail crossed that made by the ancient footprints, we had seen the path on which we came reach down across still greater depths of strata in the gorge below. And we knew that this further volume of history extended into periods that already represented a distant past at the time these imprints were being made.

Looking out over the gorge with its wonderful records we were impressed beyond measure by the effects of the power that opened the earth to make this chasm, and by evidence of vast forces involved in building and moulding the world everywhere laid bare on the walls. It seemed that, with all its overpowering grandeur, the Canyon could tell us nothing so impressive as the story of making the earth, opened to view along this path crossing from to-day to yesterday. But when, in the midst of evidence of vast changes in the face of nature, we saw the touch of moving feet, still fresh and clear upon the sand, the ancient earth with its unstable continents and shifting seas was transformed from a theatre for play of lifeless forces to the scene of eons of growth and struggle in a world of living things. Expressing with surpassing vividness the reality of beings that walked about on feet like those of man and beast, these traces on the shore brought clear realization that in this early time life resembling ours was making its way and meeting the difficulties of a changing world. With this added story the record of the great gorge was given a meaning such as it could otherwise never have possessed. The creature that walked the Coconino Trail brought a message, which made us see the majesty and beauty of the Canyon as a background, over which there moved a picture of that greatest of all dramas—the story of life.

After a morning spent in learning something of the account of ancient life given in this record of the rocks, we stopped for rest and luncheon under a juniper on a steep slope near the trail. Mike sat quietly looking out over the Canyon where we could see the Coconino sandstone marked clearly in its place among the strata on the opposite wall. Then, turning quickly, he asked me how far the makers of the footprints had probably travelled. I said: "Do you mean horizontally or vertically? We have a moving picture of them as they passed. We cannot follow them as individuals to the journey's end, but we know that generation after generation of their descendants saw layer built upon layer above the sand in which these tracks were buried. As the pile grew they moved upward over the changing landscapes formed upon it. With passing years a sea came in to replace the land, but the procession kept on its way over other steps that the gorge has not opened to view."

We looked again at the ladders and stairways formed by strata in the Canyon wall rising around and above us. "Well," said the youngster of our party, "it was the game to keep moving and climb as fast as the stair was built."

As I think back to the thrill of this experience on the Hermit Trail, there is impressed upon me with increasing emphasis the wonder and beauty of the story one reads along the way. But I realize that with all the joy of discovery we only begin to understand the meaning of what we see.

To-day, at a time which may be merely in the beginning of a great span of earth history, we as human beings represent one stage in a procession of generations that have played the game and climbed as fast as the stairway opened. We have made our paths over continents, and seas, and through the air. We have walked back into the past across trails of almost infinitely remote eons, bringing into our life to-day the experience of this world through vast periods of trial and experiment. And yet, with all our compass of knowledge and our wide reach through time, the future toward which we travel is but little clearer than was the future Grand Canyon to the maker of footprints on the Coconino shore.

Standing on the very sands in which these traces of moving feet have remained so long to tell their story, we look up to the cliffs and out over the Canyon, seeing as reality what could have been only a vision of the future when the ancient creature pressed its feet upon the same surface. Then we turn and read the story of that still greater past opened to view in the record of the gorge below. And we ask whether, with all our knowledge of this movement of the world through time, we may not learn to build upon the past—to build, as well as wait to climb the stairways when they rise before us.

[The following section was added when this article was republished as chapter VI in *The Living Past,* and is reprinted here from pages 106–110 of that book.]

Near Carson City, Nevada, is a prison yard known over the world as exhibiting a unique chapter in the story of ancient life. This site was once a quarry from which has been obtained much of the material used in construction of important buildings in the city. As the sandstone slabs were taken out, the yard was extended over a broad floor of undisturbed rock below. On one side it was bordered by the steep cliff of the quarry, and on the other by a man-made wall.

In quarrying the building stone, from time to time remains of animals and plants were found buried in the rock. Such were the shells of clams and snails, along with bones of horse and elephant. And then, on the layer forming the floor where excavation was discontinued there appeared the prints of many feet that had left their traces before the strata above were deposited.

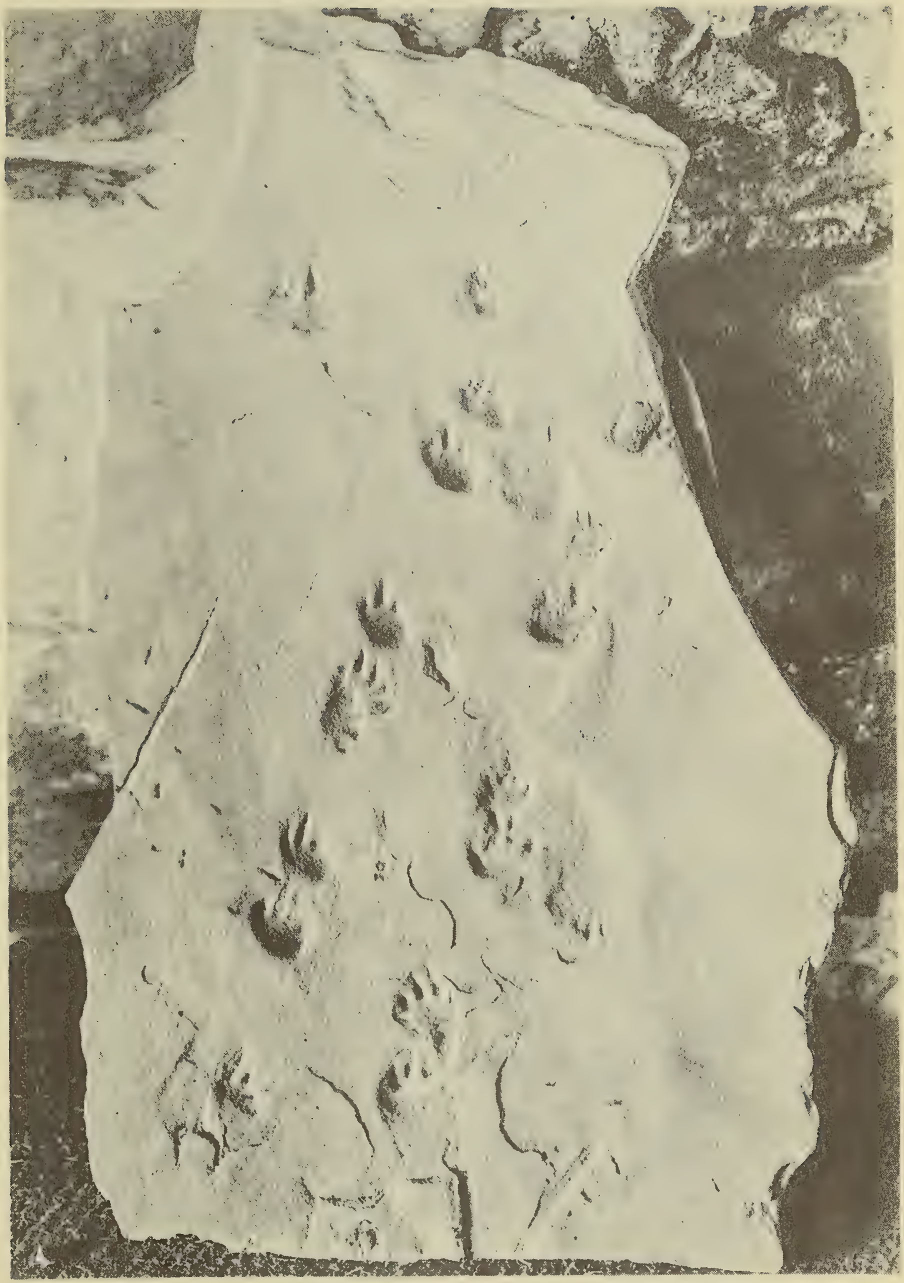
The footprints were largely those of animals we know—tracks of a drove of horses swung up to the cliff and disappeared beneath the rock above. A wolf walked in another direction; many prints of feet of birds, a large cat, and an elephant with tracks more than twenty inches across, also came to view as the rock was stripped away. And among others there were numerous tramped-in traces of a large, heavy animal, into whose tracks the perfectly preserved foot bones of a great extinct sloth-like animal are found to fit with exactness.

A tunnel was cut to follow the footprints of the elephant, and one may go beneath the cliff to see the trail that was made when the clayey surface was a part of the face of the landscape, and the rocks above had yet to be transported as sand to build the strata composing the wall above.

As one comes from the tunnel there is a feeling that the past is left beneath the rocks. But across the court in the solid stone of the floor we recognize other prints of feet such as we have seen by the roadside just outside the prison wall. They are the evidence of life as we know it to-day. When they pass beneath the cliff we seem to see the living present reach back into a distant past that also lives.

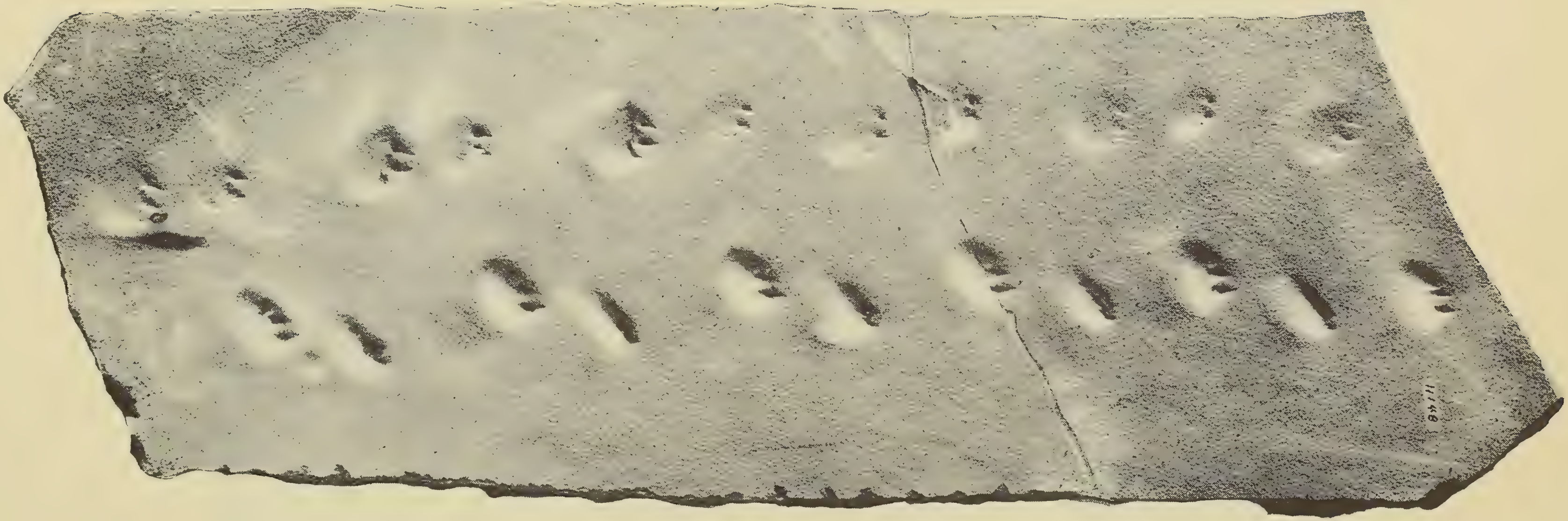
As men move to and fro across the yard on business with immediate human import, one realizes that however much this strange occurrence of ancient relics may excite curiosity and scientific speculation, its ultimate value must be estimated in terms of human life. There is no better illustration of my meaning than that given by the story on the floor of Carson Prison.

Of all possibilities in the world, a prison provides the situation in which meditation on the past might be expected to have largest place.—I often wonder whether at Carson Prison Yard the men who have constantly before them this almost miraculous preservation of evidence of what happened in a remote age, consider it a suggestion that no time is too long after an event for the uncovering of what has happened. Or does it indicate to them that not years, nor the elements, nor anything, may take away the influence of a mark once made? Or is the story to them as I would see it—that is, the evidence that in this changing world in which we live there is always hope that something better may be built?

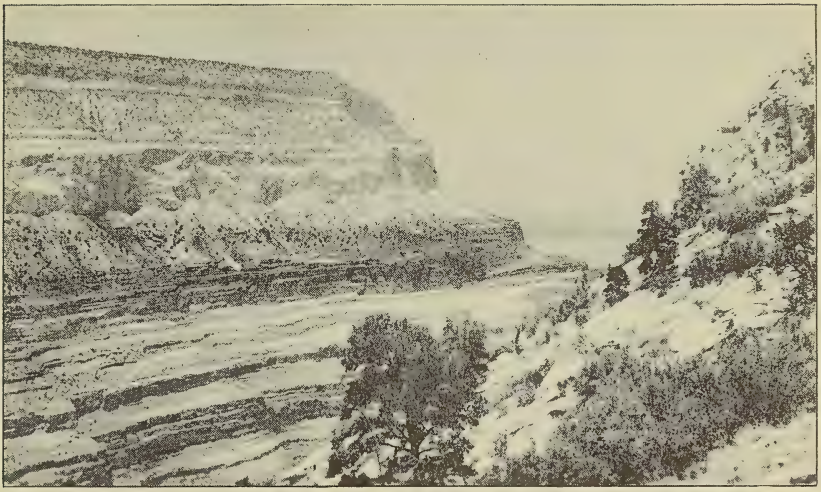


Courtesy of the National Park Service

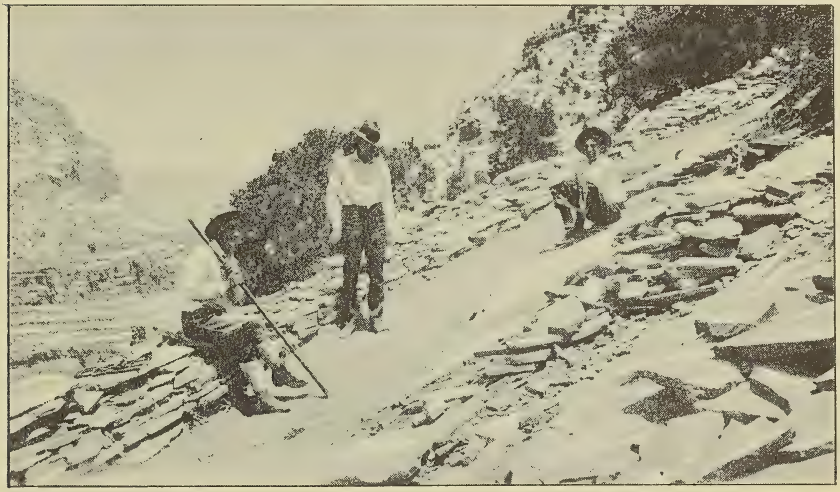
Footprints on ancient sand layers which form a part of the walls of the Grand Canyon



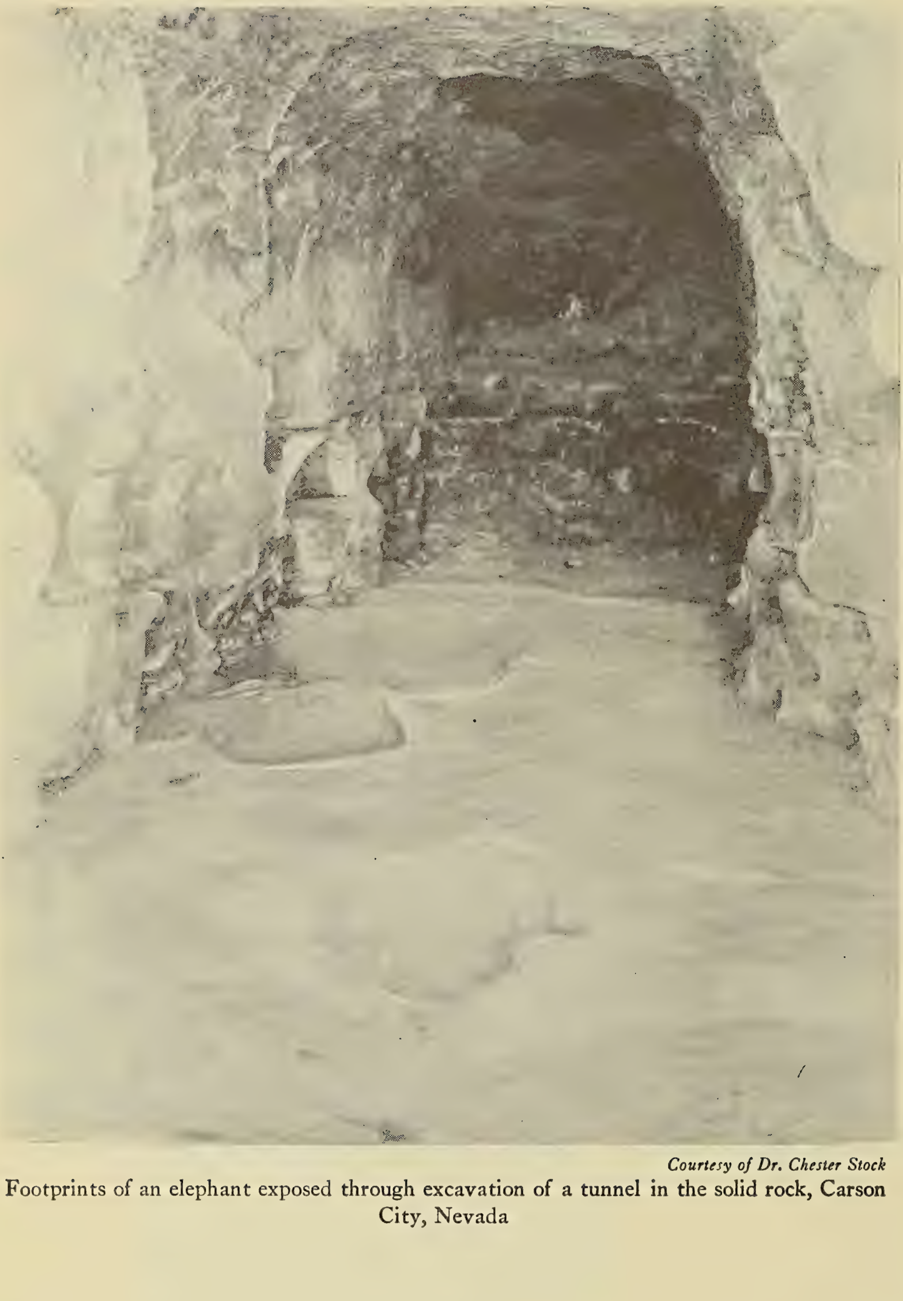
Footprints of a single individual from Coconino sandstone on the Hermit Trail, Grand Canyon of Arizona



Looking across Hermit Basin, in the Grand Canyon. The Coconino sandstone is included in the lighter portion of the section in the opposite wall.



A portion of the Hermit Trail bordered by slabs containing fossil footprints. Grand Canyon.



Courtesy of Dr. Chester Stock

Footprints of an elephant exposed through excavation of a tunnel in the solid rock, Carson City, Nevada

ARE THE DAYS OF CREATION ENDED?

"Has nature, in her calm, majestic march, faltered with age at last?"—*Bryant.*

The general unsettling of human relations which came as a consequence of the World War raised wide questioning as to the future of civilization and the ultimate fate of mankind. Evidences of disintegration in so much that had appeared fixed in social organization naturally caused us to review the guarantees of orderliness and progress to which we had been accustomed. In consideration of such questions we have naturally come to inquire as to the expectation of continuity in the process of creation, so marvellously expressed in the history of the world up to this time.

Many practical persons assume that no special reason exists for concern with anything that moves so slowly that it does not make itself felt in a measurable way in the special interests of a single generation. But we must remember that society is a continuing thing, not limited by generations. It is interested in its own future, and whatever touches this concerns also the immediate personal relations of all individuals involved. There is certain to be wide difference between the psychology of persons in a world expecting progress and one anticipating stagnation or decay. This will be true regardless of immediacy of either progress or disintegration.

There is nothing contributing to the support of our lives in a spiritual sense that seems so clearly indispensable as that which makes us look forward to continuing growth or improvement. It is difficult to believe that human life could exist without such expectation. Whatever concerns the basis of this belief is vital.

Nearly every people with a history sufficiently long to permit accumulation of results from mature thinking has set down some form of expression of its views concerning the meaning of its own creation. In a great percentage of these statements the central thought is mainly that we have not always existed, and must therefore have

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been brought into being by forces beyond human control. It is not improbable that in certain of these stories, as in those of India and Egypt, there is more than a mere statement of the fact that we were created. There are not only suggestions as to the steps by which our environment was prepared, but stages in the development of man himself seem to have been considered.

With advance in interpretation of nature by modern philosophic science, we have come to learn an extraordinary story of the history of our earth and its inhabitants. While science has not attempted an explanation of ultimate origins, it has gone far to show how nature and man developed to their present state.

The astronomer and geologist have left us no room for doubt regarding the vast extent of time in which the world has existed; the geologist has given us a moving-picture of our earth through a long series of stages preceding that in which we know it to-day; the palæontologist has made us acquainted with innumerable changes in life of the earth leading up to appearance of man and then on to the present. The biologist has come to understand something of processes by which life produces life, and of principles which control production not merely of new individuals but of new kinds of living things as well.

As I see the meaning of these advances, the great contribution through science is not merely in the fact that we learn of our having been created—we knew that already—nor in the idea that we have a history, as everybody suspected that also—nor yet in the evidence that we have come into being through a long series of stages of growth which had not been known to us. Rather does the value of scientific contribution, in the historical sense, reside in the evidence which it furnishes that the movement shown in nature through vast ages makes known in some measure the character of the thing with which we deal. Science expresses the idea of unity in nature and its laws, and continuity in their operation. It indicates that what we see does not merely concern man and the present day, but is something larger than present or past alone.

The greater part of the history of our earth is a matter for consideration of the astronomer. Geology deals only with its most recent events. In its relation to the extended reaches of astronomy, geological history shrinks to a relatively minute stretch in the field of time.

By the method of measurement now used it has been shown that our solar system is a mere speck in that great assemblage of stars which we call the Milky Way. We begin to form a conception of the size of this realm when we realize that it takes light, travelling at the rate of one hundred and eighty-six thousand miles per second, a time estimated at more than one hundred thousand years, to cross this star field.

But the astronomer does not permit us to rest with these figures as finality in measurement of space or time. The Milky Way in which we live is a unit field of stars hanging in space, and there are other bodies which resemble it in the region outside this star system. The spiral nebulæ, among the most beautiful objects of the heavens, lie beyond the limits of our special universe. Many of these nebulæ seem to represent other universes, comparable to our Milky Way. Perhaps they attain dimensions even greater than in our system, but are so far removed that only the light-gathering power of a great telescope makes them visible. The distance of such bodies may be almost beyond our power to appreciate. The elements of time involved in this story, as we read it, are beyond adequate expression, but this question of time and space has its intimate bearing upon the problem of the continuity of conditions which make life possible upon this earth.

The record of the rocks, from which we read geological history, does not cover more than a small portion of the past of this planet. We find that the most ancient strata observed are, by reason of their great age, broken, shattered, and changed into new mineral combinations by pressure, heat, and other forces. These oldest known rocks rest upon a basement which was once molten material that has come into its present position since the rocks now above it were formed. The oldest strata thus far examined rested once upon a foundation which represented a still earlier time. That basement is now destroyed or replaced by melted rocks of later date. It thus appears that we have lost the beginnings of our geological record, and there is reason to believe that what is lost may represent a period as long as that covered by all of the strata that remain.

What we have left of the record is not, however, an unimportant story. The strata available when carefully pieced together give a total thickness of more than fifty miles. Calculated by various methods, the more conservative estimates of the time required for accumulation of this pile are now measured in hundreds of millions of years, with the tendency of leading geologists toward lengthening the time to cover at least one thousand million years.

There is much evidence in the rocks indicating the conditions of atmosphere and temperature under which the successive strata of the geological record were deposited. It has been possible to form a fairly clear picture of the many climatic variations to which the earth has been subjected within the range of our available record. At one time it was believed that the climate of early geological periods was relatively very warm, and that as ages passed the earth cooled down to a condition illustrated by the glacial epoch immediately preceding the present geological stage.

The most recent studies have shown that in the known period of earth history there is no evidence of very great change in climatic conditions of the earth as a whole. There are records of many glacial periods, some even in the earlier ages. There have been many minor changes from warm to cool periods, and the reverse; but, in general, the physical conditions obtaining on the earth one hundred million or more years ago were not materially different from those on the world, as a whole, to-day. This statement should not be interpreted to mean that minor changes of climate have not taken place within this vast period. There have been almost continuous climatic fluctuations, but the extreme range has been within very narrow limits. So closely has the range been restricted that in terms of the changes expressed in the physical evolution of a star or a planet the difference between climate of the earliest geological stages we know on the earth and that of the present is almost negligible. This means that in terms of evolution of heavenly bodies, the vast geological history of the earth now open for our inspection is probably only a brief span compared with the preceding astronomical and geological ages of which we have no record —and that, judging by history as we know it, there is no reason why conditions like those which have obtained here for long ages should not continue, without material alteration, for a further period comparable to the time of which we have knowledge.

It was for a long time customary in physics and in astronomy to look upon our solar system as a mechanism of the type of a clock rapidly running down. The sun has been assumed to be growing cold. Inasmuch as the earth is dependent for its heat upon the sun, many have looked forward to a dead earth, the disappearance of life, extinction of man, and many other natural consequences following in the train of this physical change. Recently, however, it has been shown that the life period of the sun may be enormously lengthened by the breaking down of matter into radiant energy. This, it is held, will lengthen the life of the sun many thousand times, and by this change there is opened the possibility of the extension of conditions of temperature which govern life upon the earth for a period of vast extent.

Knowing that present conditions of atmosphere and temperature reach back to earliest known geological records, it is not surprising that with continuing search the palæontologist and geologist have found evidences of varied life in earlier and still earlier strata, until there are now known in the older groups of rocks sufficiently well-preserved traces to tell us of living things which existed in that early time.

Many of the most ancient rocks have been so crushed or otherwise altered that they have lost their original character entirely. Such strata could not be expected to contain remains of animals or plants, even if they were entombed in them at the time these rocks were forming as layers of mud, sand, gravel, or other deposits accumulating naturally in ancient seas, lakes, and rivers.

Remains of life from the older rocks are not limited to the simplest forms found on the earth, but are of many kinds. If the evolution theory presents a true picture of history of life, the earliest types should be the simplest stage, from which the more complicated forms would later be developed. It has been assumed by some that as this ancient life is fairly advanced and differentiated it furnishes definite evidence contradictory to the theory of evolution; but when we remember that the earlier part of our geological record is absent because it was destroyed, we recognize the earliest known stages of life as just what we should expect to find under known conditions.

We do not know when life appeared upon earth. Presumption favors the view that we shall never find the portion of the geological record which might contain this evidence. If existence of life on this planet is governed by presence of physical conditions, in a general way comparable to those which now obtain, living things may have been present here in time preceding our first record, for a period as long as or longer than the entire space of known geological history.

Just as we realize that while our total geological record is only a part of what might be known, but is none the less a vastly long period measured in terms of human history, we should understand that, though we do not see the beginning of life history, the record now open to us is actually of great extent and tells much of the nature and movement of life.

Somewhat in the manner in which physical conditions on the earth show continuous variation, so our record indicates that life changed continually through geological time. Each stage of the geological record is characterized by remains of animals and plants similar to and yet mainly differing from those of immediately preceding and following ages. While fluctuation in physical conditions between the beginning and end of the record available has not resulted in marked deviation from an original standard, we find that in history of life the changes are in general cumulative modifications in definite directions. The fossil remains found in rocks of each stage of the record are not merely different from those representing life of other periods, but they form series in which the representatives from earlier time are generally of less complicated structure. In terms of the nervous system, the older forms were less intelligent.

The facts of occurrence or succession of remains of living forms indicate that they are in the order in which they would appear if the life represented in the strata formed in each successive period were descended from that of the preceding period, but had been modified away from its parent stock in the process of descent. Thus we have the suggestion that the whole succession is connected through blood relationship.

This trend of movement or of growth we see operating continuously from the time life appears in the geological record up to the present. The movement comes to be recognized so clearly as a habit of nature that we are surprised, and seek for explanation if an apparent exception appears.

The question as to what made organisms pass through this long series of changes represented in the geological record must be answered by the biologist; as also the inquiry as to how these modifications are related to variation in physical conditions of the earth which has formed their environment during this period of change. Biology has made great advance in those studies of variation in characters of living types of animals and plants which will be necessary in approaching the solution of these problems. We know, first of all, that we must account for the origin of individuals and of races of living things by their development out of preceding or ancestral types. While there may be foundation for belief in the generation of the simplest forms of biological mechanism from things which seem to be nonliving, there is no ground for belief in the origin of any higher form of life except by birth from other life.

Development of the individual has been the subject of exhaustive study covering processes of reproduction and growth, until we begin now to understand the meaning of change from one generation to the next. The problem of how a new kind or variety or species of life comes to be derived from another we find involved in study of the mechanism by which individuals originate, and also the manner in which the individual relates itself to its environment. One group of biologists holds that in the origin of new forms the major emphasis is to be placed upon the mechanism of inheritance; another that environmental influence is the factor of major importance. Others consider that each of these factors is important; heredity being the gravitational element which holds nature steady; environment, through a wide range of complicated relations, tending to make the individual and its descendants accommodate themselves to the shift of their surroundings.

Regardless of the particular theory used in explanation, there is reason to believe that the influences governing known development of life through the ages are related in part to variation in physical conditions at the same time in different places. Moreover, we know that the crust of the earth has been in almost constant movement through geological time. Mountains have grown up and been worn down. Great land areas were lowered and became groups of islands, or have disappeared entirely beneath the sea. At other points uplift of the crust raised the sea-floor and formed land. These fluctuations in the position of the earth's crust, together with the influence of changes in climate, have forced life into almost constant adjustment, either to new conditions in the same place, or to similar conditions in different places, and have thus been either the cause or occasion of continuing migration and continuing development of new forms of life.

The relationships which we find expressed in the history of life indicate that, given a mechanism of the type which life represents, we may expect it to vary, change, progress in an environment such as that furnished by our earth. It would probably require intervention not unlike that which would be implied in the halting of gravitation to stop this continuing change if an approximation to past variation in physical conditions continues.

Let us now recall that vast as the period seems during which life has existed on the earth it may be only a fragment of history geologically, and is presumably a mere moment measured in our astronomical history. We note that variation of physical conditions during this period has been within extremely narrow limits. Unless some new element is introduced to influence earth history, what we now know of factors governing the life period of the sun, which is the source of heat and light on the earth, makes it difficult for us to imagine conditions changing so radically as to prevent existence of life on the earth for a long period to come. Given continuity of present conditions we should assume that variation and evolution or forward movement will go on for yet a very long time.

This growth or movement of life is characterized at the same time by instability and by progress. It is a process of creation, in that it constantly brings into being types that have not existed before. In the biological sense it is a continuing process which should proceed without interruption unless some new force is introduced to arrest it.

When we consider the place of the human group in this world of life on the earth we realize that man is not a creature of the present day alone, but that he comes out of the remote past, and his history merges into that of the cave-bear and sabre-tooth tiger. Man evidently came into being as a part of the world of living things by a process of creation which did not differ materially from that by which other organic types arose. He appeared at the moment in geological time when we would expect him if he is a product of growth out of a lower substratum of life. His course of history follows laws of distribution, variation, and progress illustrated by abundant examples in the whole life world.

From stage to stage, through a period which seems vast, measured in terms of so-called human history, we find the man type changing its form and approximating more and more closely to the specific kinds of specialized and highly intelligent human beings of the present.

To-day we see man distributed over the whole earth, varying widely in physical characters in different parts of his habitat. He shows a relation of his physical differences to variation of environment in a manner similar to that exhibited by the wide range of animals and plants known so well through our studies of distribution, variation, and evolution of organisms in past periods.

At the present rate of progress it seems quite certain that within a few centuries the human race will have almost complete control of the biological world. Man will take what he wishes. He will determine what plants and animals he desires to retain, and what may be eliminated. Much of the power of nature will be harnessed and directed to his use.

When we consider the relation of future biological or creative evolution to human beings we find a number of leading students inclined to believe that further development of man will be shifted entirely from physical to so-called social evolution, involving development of institutions with accumulation and organization of knowledge. This social development is characterized by its relation to a train of continuing experience. Individuals disappear but the body of knowledge and the consciousness of society persist. In this phase of evolution discovery and research contribute by bringing in new knowledge, science and learning serve to organize information, business makes knowledge effective, education carries it from one man to another or from one generation to the next. The body of knowledge involved in the social organism may grow indefinitely. There seems almost no limit to the distance which humanity may go in increasing acquaintance of its environment, as well as in understanding the individual and social characters of human beings.

There is, however, a limit to which knowledge may be used by man. While we have in a certain sense a social consciousness, a mob mind, and a racial mind, in the last analysis, expression of all these things must come through the individual. We must not forget that individually we are sharply restricted in extent of our experience, in possibilities of accumulation of knowledge and wisdom, and in our capacity to use the great stores of information even when secured.

The future of mankind in the social sense depends then not alone upon our capacity to accumulate and to organize. Ultimately, in handling our greatest and most critical affairs we must depend upon the capacity of individuals to understand and to utilize the materials thus brought together. The success of democracy depends in large measure upon selection of individuals with adequate ability for performance of great tasks. Our success depends also upon the possibility of having the social world so organized and trained that each element in the complicated machinery will keep understandingly to fulfilment of its duties, so that the whole mechanism may operate in orderly fashion. It is probable that we could learn to handle this stupendous machine provided all the parts could be kept in perfect adjustment. But not only do individuals have limited capacity, they have also emotions, and desire for individuality. Independence is one of the most marked qualities of human beings. These are factors which bring almost infinitely complex elements of disturbance.

To the difficulties mentioned there must be added a further limitation arising from the fact that generations of people are replaced by others with great rapidity. No sooner have we trained an individual or group to a particular habit of conduct than another generation comes upon the scene and the educational processes must be repeated. These conditions relating to the place of the individual in the complex of society mean that, not only must we know how to control the machine, but the individuals who operate it must have extraordinary knowledge and experience, making it possible for them to bring about continuous readjustment of the parts while normal changes are in progress.

With continuing increase of knowledge and of complication in our social machinery, a limit must be set beyond which it will be extremely difficult to handle forces which we organize, unless there be opened also the possibility of development of the individual in the sense of enlarging his capacity for knowledge and ability to use it.

The limitations put upon social evolution by reason of restricted capacity of the individual make us consider seriously the question of further evolution of man in the sense of development of body and especially of brain. For use in such study we must have the best possible understanding of the laws which have controlled biological evolution in general through past eons. This type of progress depends upon our securing a fuller understanding of all questions concerning human variation and race differentiation, and of relation between purely biological factors and social factors.

We have learned that, through five hundred million years or more of history of plants and animals, organisms of this world have shown themselves amenable to laws which have produced adjustments to varying conditions and forward movement from age to age. The student of living things has found, combined with stability of hereditary tendencies, the operation of factors which determine that no two individuals shall be alike and no two generations alike. Our knowledge of life in the widest sense indicates that, in a world such as this, the tendency to variation and to progress is as near to being truly characteristic of life as are any qualities which we might consider distinctive of that state of being.

We have then to inquire whether by reason of man's intelligence, because of the fact that he has come to know and control nature, because he has attained most nearly to godlike characters, he could be the only organism in the universe unable, either naturally or through exercise of intelligence, to take advantage of the laws by which the organic world has steadily advanced.

It is true, as many have suggested, that with his increase in knowledge man encounters new dangers through widening opportunity for evil, which places obstacles in the way of his progress. Frequently he handles great forces of nature, or directs organized human emotions with little knowledge of results to come. The largest danger lies, however, not in new knowledge of nature but in man's ignorance regarding himself—both as an individual and in the mass. It is true that man makes new toys and instruments which he sometimes uses unwisely. But we must be clear that increase in knowledge offers not merely opportunity for evil. At the same time it opens greater opportunity for good, together with better ability to choose between the evil and the good. We should have no sympathy with the suggestion that civilization is a disease which halts evolution and leads us to destruction. It is the natural development of human life, following the discovery and organization of knowledge.

Civilization need not destroy us. If we suffer it will be because we refuse to recognize that man is himself the greatest of all subjects for study that the universe has as yet produced, and that we know less of his nature and capabilities than of many aspects of the natural world toward which our investigations have been directed. We need for the safeguard of our future more knowledge, better organization, better education, and especially the results of wider and a deeper research on the nature and personal values of human beings than has yet been accomplished. When this is done we may trust man in his use of the tremendous opportunity for creative work in the advancement of the race.

And, to return to the thesis of this paper, we need for man that opportunity for forward movement or evolution in his physical being which may enable him, not only to add to his accumulated information, but to increase the possibility of using his knowledge to full advantage. There is, I believe, reason to expect continuation on the earth of those conditions physical and biological which have made evolution possible in the past. In this environment the life world should remain flexible and progressive. Man will be a controlling or guiding factor in the evolution of animals and plants. It is for me impossible to believe that with the great scheme of development of this universe, carried on through almost endless time, we can imagine evolution halting because of the possibility of destruction or disintegration due to the advance of intelligence in the created. We are safe in assuming that in addition to the natural tendency of organisms to vary and to progress we shall have the understanding and guiding mind of man to take advantage for himself, as well as for other living things, of the laws which he will come to know, and which he will also wish to use in his own striving toward the goal of betterment.

So, as we read the history of man and appreciate the dangers of his advance in learning and in civilization, we may realize that we are taking for our use that dangerous fruit from the tree of knowledge, and may question whether we can bear the consequence of coming to view the world as gods. At such a time it is proper that we turn in reverential inquiry to view the record of the past through which creation has revealed itself. There we find a history open for our information. It tells us of the forward movement of the world from which we have grown, and in which we are a part.

What greater gift could we receive from a beneficent Creator than to learn through evidence there presented that the conditions which have governed the creative process are those which operate to-day and should be expected to continue; that the power behind nature is with us as in the past, keeping the world a place that may be ever new, and justifying faith that progress will extend itself into the future?

LESSONS OF THE PAST AS GUIDES FOR THE FUTURE

It is hardly possible to listen in on a radio program without being conscious of the fact that in an almost miraculous manner modern science is bringing us into touch with an immense number of new interests. And in a multitude of other ways science is increasing our acquaintance with the world about us.

Hidden Meanings Revealed

In these days everyone knows something of life in central Africa and of the conditions at the North Pole—of the nature of the sun and of the vast distances of the stars; we even have somewhat of an appreciation of both the minuteness and the power of the atom.

It is a part of my purpose to show that, as important as is this increase of what we know, of still greater significance is our beginning realization that these revelations represent something beyond an appeal to mere curiosity.

Science has demonstrated that the seemingly endless and widely separated parts of the universe are all so related that we can no longer think of any thing or of any fact as being completely isolated. Even in the so-called practical sense it has proved true that each discovery, directly or indirectly, brings something of real human interest and importance.

Our appreciation of this human value of new knowledge has been made possible largely by technical studies of investigators. But it is a characteristic of modern thinking that we accept such views rapidly or slowly according as we can verify the reality of what is described.

Although the subject of this talk relates to the human significance of events far removed from us in time, my meaning may be made clearer by an illustration representing verification of reality of things vastly removed from us in space.

Radio address given under the auspices of the American Association for the Advancement of Science and of Science Service, December 1928. *Carnegie Institution of Washington News Service Bulletin*, serial no. 38, 1929 series no. 7, pp. 49–54, April 21, 1929.

A Great Meteor Visitor

I have long had what might be called a reading acquaintance with astronomy, and have daily watched the sun, moon, and stars. I have passed examinations relating to tidal influence of the moon, and variation of the seasons due to our relation to the sun.

But it was not until at Meteor Crater, Arizona, I stood on the brink of a great cavity nearly a mile across, which had been smashed into the hard rocks by some tremendous mass falling from the skies, that I appreciated fully the reality of the world of things in outside space.

I remember that a friend who stood with me looking into the opening said, when we found a piece of the meteor, "Well, there *is* something out there in the sky *after all.*"

As we were climbing down into the great hole made by this messenger from the outside universe, my friend pointed to the wrinkled face of the moon, hanging just over the edge of the pit, and expressed the hope that we could sometime experience the reality of a body actually floating in space around us—and that we might appreciate it with a degree of assurance comparable to that inspired by the meteor crater itself.

Weird Landscape of the Moon

Less than a year later we two sat together viewing the moon from the observing platform of the 100-inch telescope of the Carnegie Institution at Mount Wilson.

Looking over the level upper edge of the moon's surface we could see across wide plains bordered by tumbled masses of mountains and huge craters.

The weird landscape gave us the same thrill that comes to the scientist or explorer as he passes on the train through a strange country, with distant peaks and canyons that lure to adventure and discovery. So fully real was the scene that we even selected the localities where we would wish to camp in order to study the wonders of the place.

And so it came about that, added to the thrill of reality produced by the great meteor visitor from outside space, we had *as much as visited* the nearest of the great bodies lying in the world beyond the ceiling of our own earth.

The riddles of distant space are not all solved. But astronomy has given enormously to physics and chemistry, which in turn contribute so much for human welfare. The knowledge of what lies in the almost infinitely remote regions about us is becoming so fully established that we discuss the forces involved with almost the freedom with which we consider materials on the earth.

In the same way in which we appreciate reality of what have seemed intangible things in space, I wish for a few moments to suggest extension of vision into the vast reaches of past time, and indicate there a corresponding expression of reality. I can best make my meaning clear by concrete illustrations.

Rancho La Brea

When the first Spanish exploring expedition passed through the region near Los Angeles, it discovered a place where pools of asphalt or "brea," as the Spaniards called it, were seeping out of the earth. In time this region came to be known as the ranch of tar, or Rancho La Brea. The pools were operated by their owner as a source of asphalt.

Laborers dug out the material and cleansed it by heating it in large vats. The impurities, consisting mainly of bones, were separated by pouring off the liquid asphalt. Many of the skeletons were recognized as differing from those of living barnyard animals and from the coyotes and squirrels commonly found stuck in the asphalt.

Many years ago it was my privilege to make a rediscovery of the nature of this great collection of animals, and to direct the scientific study of these materials. The total result of excavations brought out approximately 3,000,000 bones.

In these specimens every detail of structure was perfectly preserved. The bones were like those of recently dead cattle bleaching near by. The evidence of worn teeth rubbed down when in action in living animals—the diseased tissues of many parts of skeletons—the broken bones that had healed with imperfect contacts—the baby wolves and lions with their milk teeth only partly cut, or partly replaced by temporary teeth. It all gave an impression of reality that equalled that of any collection of living animals of the present time.

Strange Animals of Remote Time

Our studies showed that the multitude of bones included remains of a few kinds of creatures now living in the region of Los Angeles. The majority represented such strange forms as the elephant and camel, together with extinct horses and bison, and great creatures known as ground-sloths as large as rhinoceroses, gigantic bears differing from all living types, lions greater in size than any other cats living or extinct.

There was a multitude of tiger-like creatures with fangs shaped like long knives, a great extinct wolf, probably the largest of his tribe, an eagle-like bird greater then the condor, and many other birds and beasts entirely unknown, even to those best acquainted with the animal life of today.

With all the strangeness of the life represented in the collections from Rancho La Brea, there is at this locality no clear evidence of purely geological nature as to the period in which these animals lived and were buried. We are certain that they represent another time than the present, and that it extended far beyond the beginning of human history as we know it in America.

Prison-Yard of Carson City

Another locality of extraordinary interest in that it furnishes geological evidence of antiquity of life, which is in some respects similar to that at Rancho La Brea, is found within the confines of the prison-yard at Carson City, Nevada.

For many years the prison was a quarry. In crossing the excavated portion of the yard one walks over a broad expanse of sandstone slabs leading to a steep wall of undisturbed rock. Along the farther edge, from which the stone has been removed, one sees, with a distinctness which may not be questioned, the prints of many feet pressed into the stone. They were found here when, in the work of quarrying, the layers immediately above them were removed.

The prints are largely those of animals we know—Tracks of a drove of horses swing up to the cliff and disappear beneath the rock above. A wolf walks in another direction and passes beneath the wall. Many birds, a large cat like a lion, and an elephant with footprints more than 20 inches across, also approach and vanish underneath the wall.

A tunnel has been made to follow the tracks of the elephant, and we go beneath the cliff to see the trail that was made before the rocks above were formed. And then there are many footprints of a large heavy animal into whose tracks the perfectly preserved bones of a ground-sloth skeleton from Rancho La Brea fit with exactness.

Convincing Evidence

In the rocks of the quarry, and in some instances resting upon the layer in which the footprints were made, were bones of some of the types of animals, the tracks of whose feet appear in the prison-yard. Among them was a horse, an elephant, and a great cat.

No one who visits the quarry can avoid appreciation of the antiquity of the mass of rock formed layer upon layer in an ancient time. Nor can there be any doubt of the reality of the living creatures—some like those we know today—some strange to America—some strange to the whole world—that left their footprints on the sand before the rocks above were made.

The proof of reality of a world of creatures differing from what we know today as seen at Rancho La Brea—and the unavoidable evidence of similar creatures that moved alive over the sands of Nevada before the rocky hill at Carson Prison was formed—these serve as a basis for interpretation of the tremendous spectacle of life passing through the ages as we see it at the Grand Canyon.

Life Spectacle at Grand Canyon

One is impressed on arrival at the Grand Canyon by the immensity—even of the silences—so deep that no sounds come across. Brass bands and the shouting of multitudes could have no effect. Clothed in beauty as the changing lights sweep over, it not only arrests attention but holds our interest.

One is conscious, first, of how the canyon was formed by the rushing river below—and then there is the evidence in unmeasured piles of strata that there must have been vast ages of building.

One goes down—and as the mule zigzags back and forth, there appear, in the face of the limestone cliff, masses of shells and corals, the life of an ancient sea—and then, deeper down, there come into view rocks, made of sand and mud, containing many prints of ferns and other plants of rich jungle-like vegetation, packed close together—and here, also, in the same hardened clay bed are to be seen footprints of many creatures that walked over it in the ancient time when the clay was forming.

Here and there are prints of raindrops from an ancient storm that swept by, just as the heavy drops fall today from thunder clouds passing over the Canyon—then down, almost a mile below, into lower rocks—rocks built of sand and gravel and clay with tracks of crawling crab-like creatures of that early time, and the remains of living things all of a lowly type and differing from what we know in the world today.

Orderly Movement to Continue

The story of the walls and of the life in them shows a multitude of modifications of living things in the periods represented. Life was constantly changing toward higher types. We see the immensity of the past and the nature of the movement in it. Not that we know yet the precise laws that governed the movement of these events, but we learn that there were laws, and we begin to wonder whether the world now or in the future could exist if they should cease to operate.

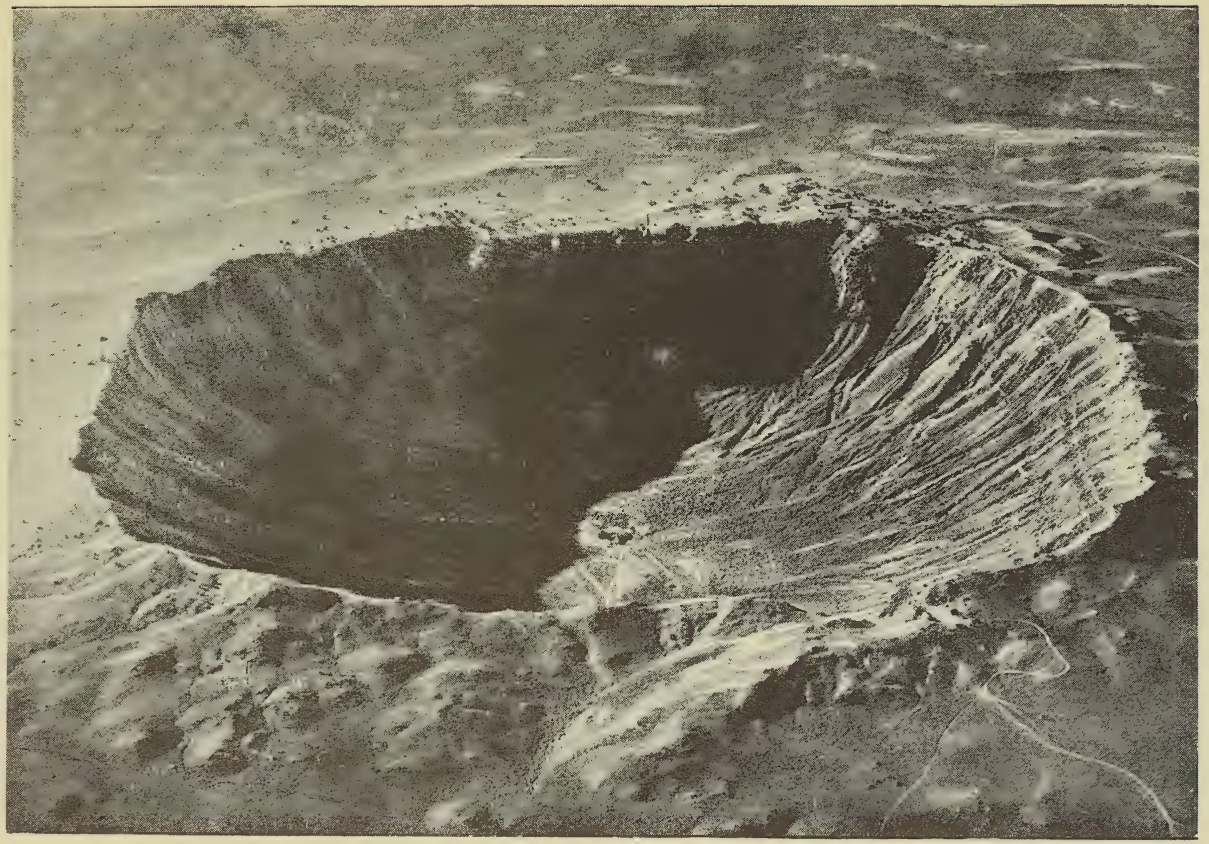
Unless there should be intervention, such as would have halted the course of nature as it is represented through the hundreds of millions of years of history in the walls of the Grand Canyon, we must believe that movements of the order of magnitude of those there shown will continue. May we not expect to know and perhaps to utilize more fully the operation of some of these laws?

Something Better May Be Built

However much the things I have described may excite curiosity and scientific speculation, their ultimate value must be estimated in terms of personal interest. There is no better illustration of my meaning than that given by the story read from the rocks of Carson Prison-Yard. Of all possibilities in the world, a prison provides the situation in which meditation on the past might be expected to have largest place.

I often wonder whether at Carson Prison-Yard the men, who have constantly before them the almost miraculous preservation of evidence of what happened in a remote age, consider it a suggestion that no time is too long after an event for the uncovering of what has happened—or does it indicate to them that not years, nor the elements, nor anything, may take away the influence of a mark once made?

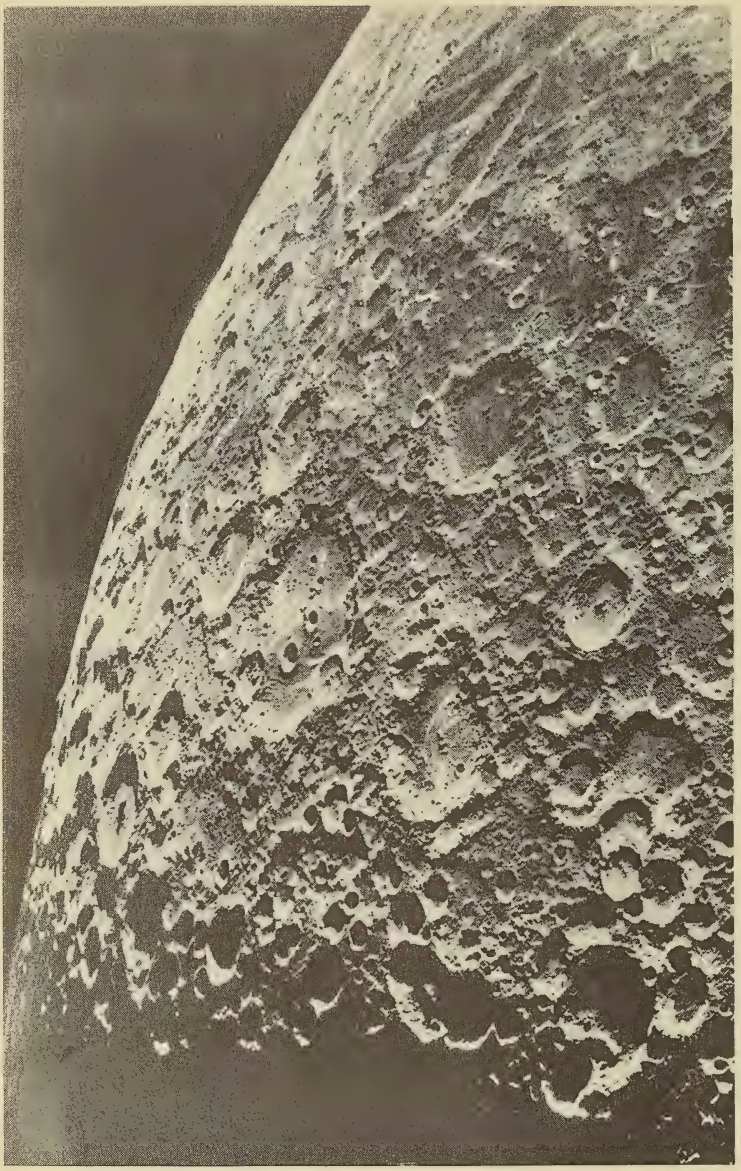
Or is the story to them as I would see it—that is, the evidence that in the changing world in which we live there is always hope that something better may be built?



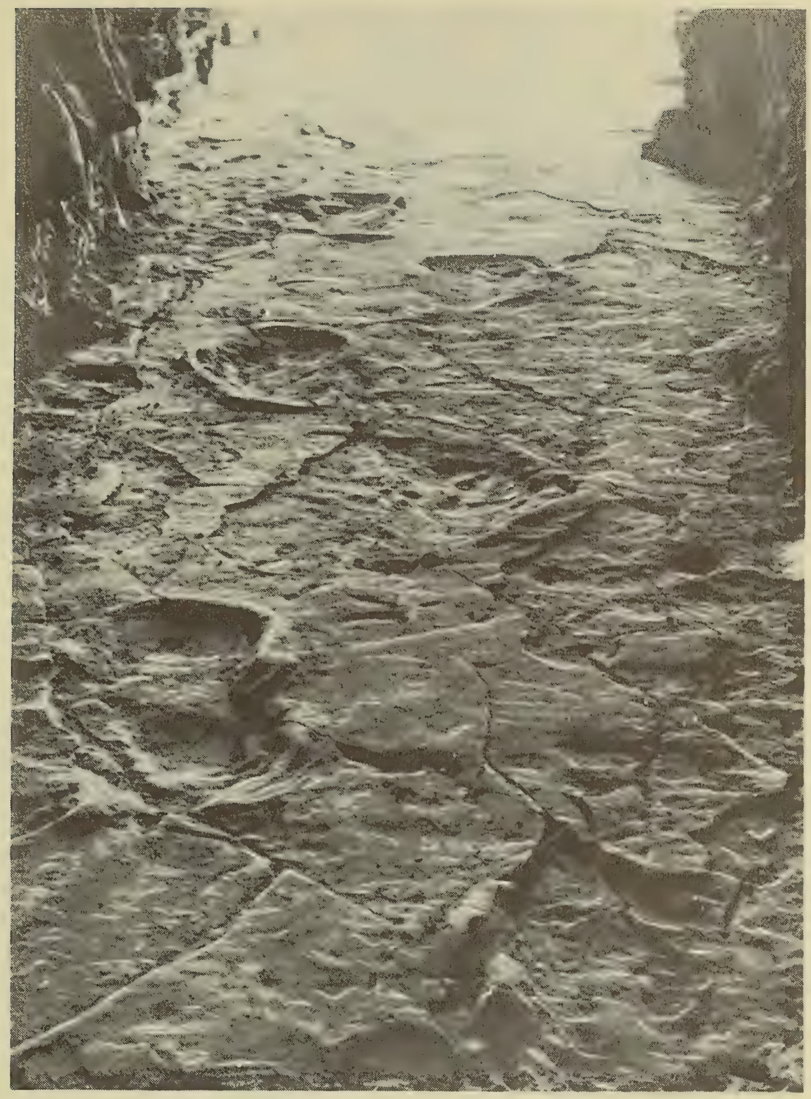
Courtesy U. S. Army Air Corps

Scientists engaged in study of the "craters" of the moon are indebted to the U. S. Army Air Corps for this remarkable view of Meteor Crater which is near Winslow, Arizona. Only a picture taken from the air, such as this, could show the close resemblance to lunar "craters" which is apparent upon comparison.

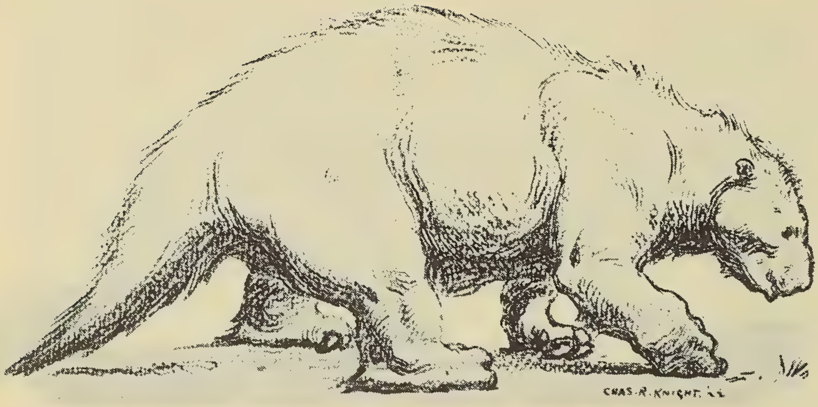
This pit, four-fifths of a mile across and 570 feet deep, is the result of the impact of what is thought to have been a huge meteorite. Evidences of a terrific collision are all about. The slopes are littered with crushed rock. Huge boulders, some weighing 7,000 tons, are lying about the slopes. Enormous rocks were thrown to a distance of half a mile. Though various drilling attempts have been made, the main mass of the meteorite has never been discovered.



A section of the moon, photographed at the Mount Wilson Observatory of Carnegie Institution with the 100-inch telescope, showing lunar "craters." 30,000 of these have been mapped. Many are larger than Meteor Crater, indeed, some reach diameters of 50, 60, and even 100 miles and depths of 10,000 feet. Some scientists have advanced the theory that each of these "craters" was formed in the same way that Meteor Crater was formed, by impact of a body travelling at terrific speed. Under such circumstances, it is conjectured, a meteor on collision would penetrate the moon's crust and set up an aureole of intense compression which would rebound elastically and eject a quantity of material. Other scientists of repute, it should be said, do not accept this as a satisfactory explanation.

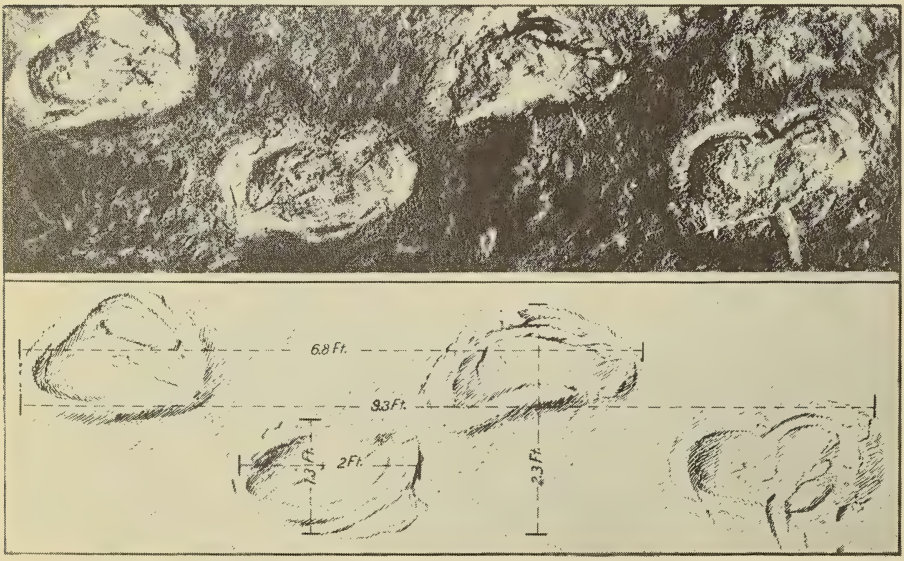


Years ago, when quarrying building stone at the Nevada State Penitentiary, Carson City, Nevada, the footprints of many animals were discovered embedded in the rock. Those pictured above bore such extraordinary resemblance to the sandalled footprints of human beings that for a time many thought that evidence of a giant race of primitive men was at hand. In 1919, however, Dr. Chester Stock, now of Carnegie Institution, found in a collection of fossils at the prison convincing proof that the ground-sloth had once lived there. He also found that a reconstructed hind foot of one of these animals, recovered from the asphalt deposits at Rancho La Brea, fitted the tracks so closely as to leave no doubt but that a ground-sloth had made them.



Restoration of a ground-sloth (Mylodon) by Charles R. Knight, based upon study of a mounted skeleton in the Los Angeles Museum of History, Science, and Art, and other fossil remains.

During the Pleistocene age (perhaps a million years ago) the jungles, forests, and rolling plains of North and South America were frequented by these ponderous and slow-moving animals. They probably wandered about in small herds feeding on grasses, shrubbery, fruit, berries, roots, and herbs. Doubtless their most destructive enemy was the saber-toothed tiger, now extinct, one of the most ferocious of the beasts of that ancient time. The only living representatives of these unique mammals are the diminutive tree-sloths of Central and South America.



Upper—Replica of the footprints of the ground-sloth found in the Carson City Prison-Yard, from a cast prepared by J. W. Lytle of the Los Angeles Museum of History, Science, and Art. Lower—The diagram indicates the size of imprints, length of stride, and width of straddle.

THE PAST AS LIVING

The words past, present, and future have such definite significance that it is difficult to conceive of anything which could change their meaning. The present is living, the past is dead, and the future unknowable. But, in reality, our appreciation of these things in individual day-to-day life is based upon narrowly-limited experience.

This may be illustrated if you have opportunity to look out over the heavens with a great telescope. The astronomer will tell you that the stars and other objects examined are so far away that we do not see them as they really are at the moment. Although light travels with enormous speed, the rays bringing the image of these heavenly bodies to our eyes require a little less than two seconds to come from the moon, eight minutes from the sun, about four years from the next nearest star, and more than one-hundred million years from the farthest objects thus far known in the universe.

So, in reality, we observe the stars and planets arranged not only according to their position in space, but with reference also to different stages in time. The nearest objects correspond as it were to yesterday, the farthest we see are actually living and functioning in the age of dinosaurs. In terms of history of the Earth, they correspond to a time before the Rocky Mountains were formed. Moreover we see all these things as fully real, and in operation at the same moment, though in different places and different ages.

In a recent speech I told this story of the various stages of time as all seen at once in the heavens, and in making the statement remarked that these relative times, depend upon both position in space and rate of communicating vibrations as represented by light-waves.

One of my hearers remarked afterward that while I was speaking the transmitting apparatus on the desk before me was broadcasting the talk throughout the city and country, and that, since there were

Radio address given under the auspices of Science Service, over the Columbia Broadcasting System, New York, May 23, 1930. *Scientific Monthly*, vol. 31, no. 4, pp. 340–343, October 1930; *Carnegie Institution of Washington News Service Bulletin*, vol. 2, no. 11, pp. 78–82, October 26, 1930.

no amplifiers in the auditorium, I was probably heard in the surrounding region before the sound reached the auditors at the back of the room. The hall was of considerable length, and the speech was being carried only by relatively slow-moving sound within the room, but by rapidly moving radio waves outside.

If, as my friend believed, the outside country was aware of each word earlier than the listeners at the rear of the auditorium, then the observing of what was happening had a relation the reverse of that described for the stars in heaven. The more remote places in space were nearer in time than those close by.

When, as in the illustrations given, one begins to recognize past and present as if together, the barriers cutting off the past seem less formidable. But, in spite of all one may say, in average human life the past is something that appears relatively valueless. We say "the past cannot be changed"—"the future can be moulded." "Let the dead past bury its dead"—"turn to the living future." And so I believe we should view the situation, unless the past is seen to live. The instant the past takes on reality, it seems almost to become a part of our lives today.—It certainly becomes one of the most important elements in moulding the future.

In general the more remote a thing seems in time, the less its reality, and with this goes naturally the assumption of its relatively sharp separation from anything concerning our personal lives. It is largely upon the vitality of the thing in the past that our interest depends.—Though fading into dust, the flower we find on the coffin of an ancient king stirs again the springs of human tears.

Recently in a great ruin of the Southwest I examined the dwellings of an ancient race that lived at Mesa Verde. The beautifully constructed dwellings, in caves high up on the Canyon wall, made one realize the presence there of many generations that struggled with the peculiar problems of that arid region.

In one room of these buildings the smooth covering of mud plastered upon the wall had fallen away. The lower coating was marked with innumerable prints of fingers. As the first masses of clay were pressed into the spaces between the stones, the marking of each finger, of every joint and corrugation had been left on the surface. This work was not merely that of indefinite beings of ancient time. It represented an individual man, who doubtless bore a name, had friends, perhaps also a family. Whether this was his home, or only a place in which he shared the comforts and protection of the community we may never know. I trust that when this particular piece of work was finished, he was cheered by having some one say, "This looks good to me."

Not far from these cliff dwellings I stopped at a trading post to buy some Hopi Indian pottery. The manager, a man with an inquiring mind, showed me a slab of rock from a nearby quarry, and upon it a peculiar impression. The Indians had called attention to the fact that in this solid rock were many "cattle tracks." Some of the trails crossed the rock, and excavation showed them continuing into the hill. The Indian knows "real tracks" from "might be tracks." He had no doubt about these particular ones. In the same formation are many skeletons, but cattle do not appear among them. The great bulk of the remains are those of ancient American camels, which also have cloven hoofs.

These rocks belong to an age antedating the last great period of mountain making in America. Millions of years would be needed to give the measure of their remoteness in time. But over this arid landscape of today the Indian pointed out the trail of cloven hoofs in the rock.

As one travels over the Earth, the wonders of these living pasts are multiplied, sometimes made known by science, sometimes by instinctive recognition of untutored students of nature such as the Indian. Always there is borne in upon one the inescapable reality of a vast stretch of time linked with the present.

Commonly the elements of the story as we find it are only isolated episodes. There are few places where one may see it illustrated in such a manner as to impress upon us the picture of its continuity and scope. As nowhere else in the universe, we find at the Grand Canyon of Arizona the evidence of moving events in the clear order of their occurrence, and so visualized that one sees, as it were, the panorama of history in operation. This story illustrates at least one thousand million years of action, and so presented that one may not mistake its meaning.

Looking out over the heavens, we see many stages of time in different places.—At the Grand Canyon we visualize a vastly longer stretch of time with all the steps or stages shown as in one place and at the same moment.

In the vast wildernesses of the past, such as are encountered in the Grand Canyon region, one may explore with a sense of reality like that in the wild and unknown places of the Earth today. The shifting continents of ancient time—the changing seas—world after world of strange forests and creatures that exceed the weirdness of fiction, pass under the adventurer's eye. So fully aware is one of what they represent that they live again.

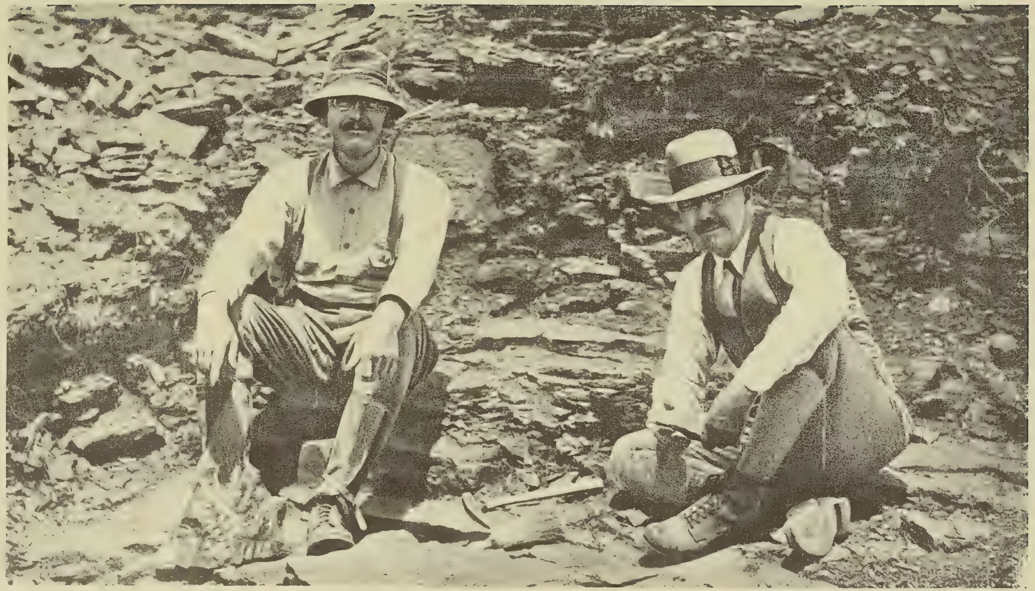
These elements of the world from past time illustrate the interlocking of events so that all appear as one story. In their continuity they also interpret in an extraordinary way the modes of operation in nature, which we call laws, illustrated in similar manner throughout time and space. Once they are conceived as reality, and as expressing a continuous process, the past becomes the basis upon which the present and future must be built.

Some years ago a man whose conduct had been investigated, because he did not agree with others as to how public affairs should be conducted, was reported to say that, considering his recent experiences, he would be happy if he could be "as sure of his past as he was of what he would do in the future." In this instance, the future was improved by study of the past.

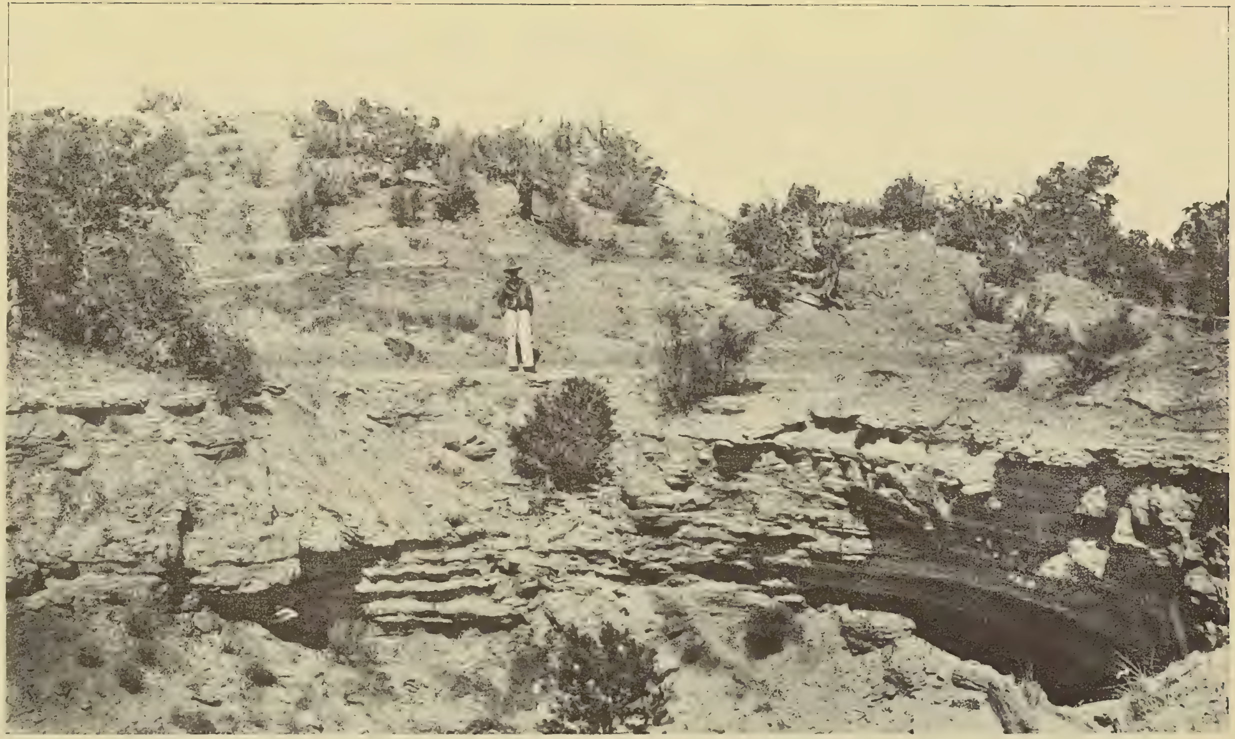
In the story of life as a whole, it is the longer reach of acquaintance with history that gives us the best guide for the future. We may not change the past, but we may build upon it. We may not wholly determine the future, but we may mould it according to what we learn from the past. Those are wisest who build upon the longest experience extended into the farthest reaches of the future.

The tendency of modern science to consider the relation between time and space, or, in another sense, to disregard what have seemed to be barriers in space and time, has made possible some of our greatest advances in knowledge. But this broad-mindedness is not found in science alone. It has expressed itself in business, where, more and more, great projects not only look forward to a distant future, but build themselves upon the broad foundations of long experience.

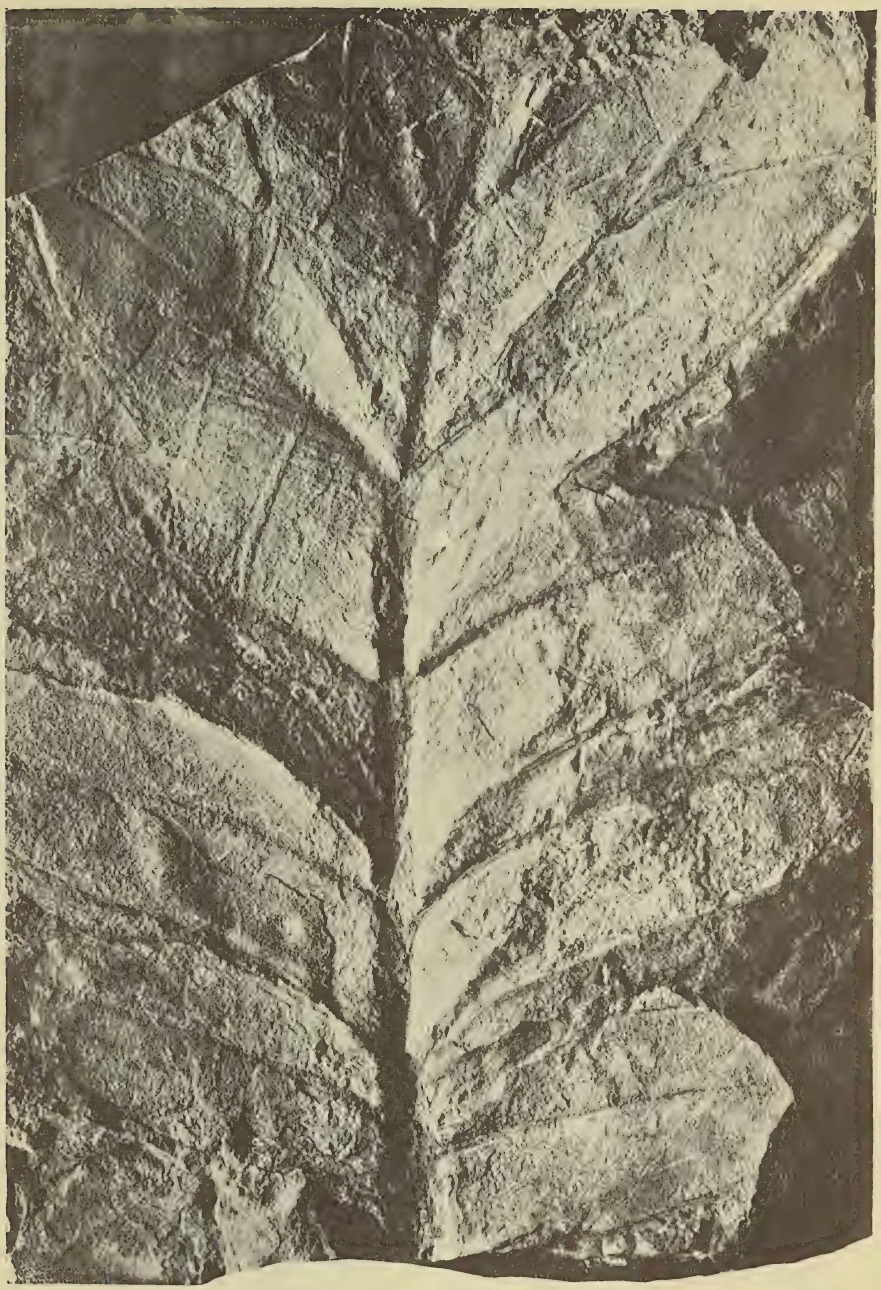
Not only is there indication of our need of knowledge for the whole of space and time. It also is clear that no one may live to himself alone. There may be no higher degree of selfishness than that of any generation which disregards both the future and the past, and denies to those who have made sacrifice the right of a continuing influence for their accomplishment.—So, as an illustration, it is a part of our duty today to guarantee that the poppies that grow in Flanders shall represent a widening circle of influence from lives that have not been lived in vain.



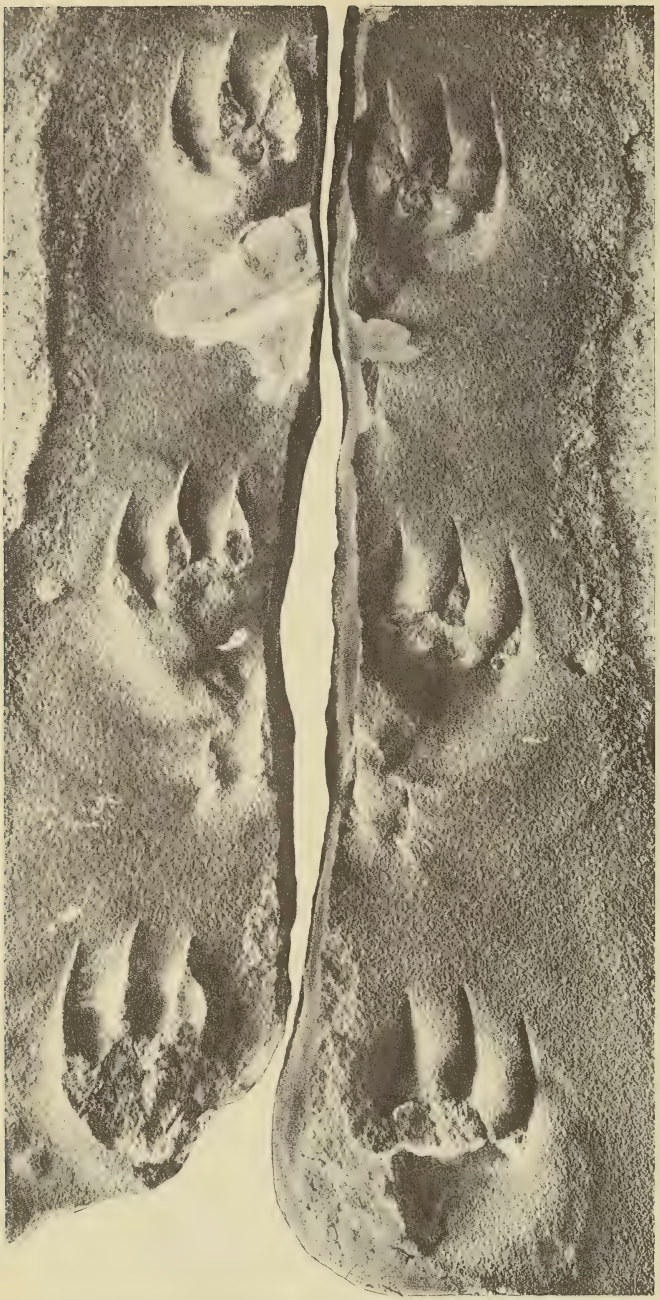
Dr. David White (left), Research Associate, and Dr. John C. Merriam (right), President of the Carnegie Institution, working in the Hermit Shale formation of the Grand Canyon in search of fossil traces of ancient life. This locality is about nine miles from the Hermit Trail. At a point on this trail, a thousand feet down from the canyon rim, a permanent "out-of-doors exhibit" of fossil footprints has been prepared. A section of the track-bearing rocks was cleared of debris thereby exposing to view an imposing group of footprints just as they were made ages ago except that the original medium of soft sand or mud has turned to stone. Note the fossil plant at Dr. White's feet.



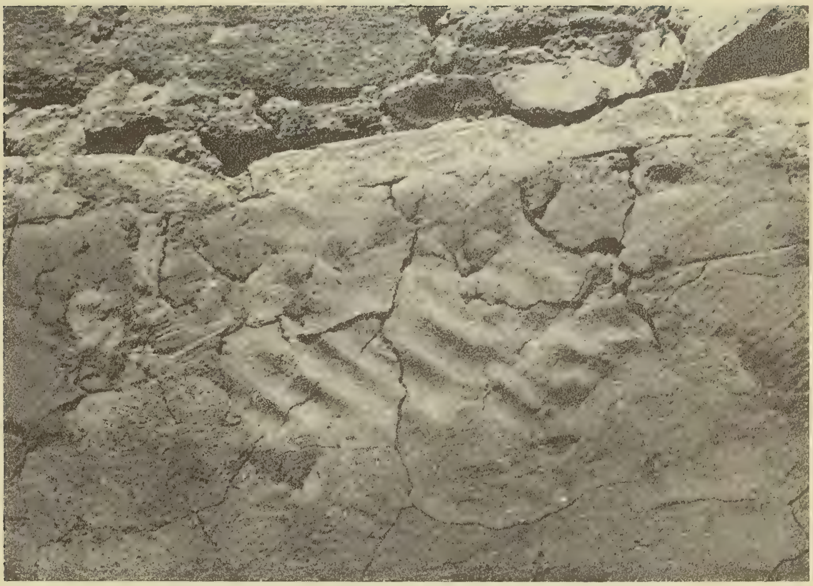
High up above the floor of Jeddito Valley in New Mexico, at an elevation of about 7,000 feet, there is a stratum of sandstone, the exposed surface of which contains more than two hundred tracks thought to have been made by camels in a remote geological period. The out-cropping of the track-bearing formation is directly in front of the left foot of the geologist who is standing on the track stratum. In the same formation are many skeletons, the great bulk of which are of ancient American camels. The rocks comprising this formation belong to an age antedating the last great period of mountain-making in America.



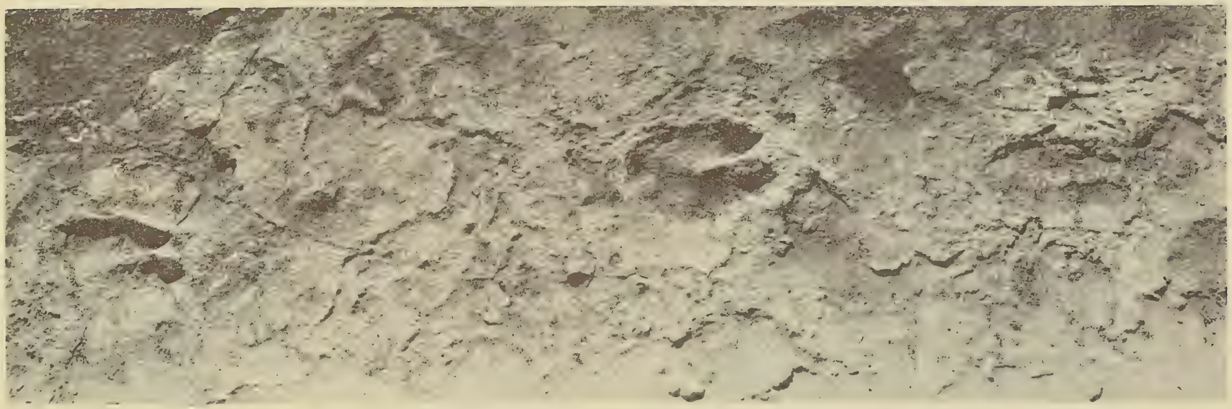
A fossil plant from the Hermit Shale of the Grand Canyon, found by Dr. David White, Research Associate of Carnegie Institution. Dr. White has spent several seasons in the Grand Canyon in study of the plant fossils of the Hermit Shale, a formation which dates back approximately to the age of coal plants, or to what is known as Permian time. The Hermit Shale has yielded Dr. White thirty-five plant species, three fossil forms probably of animal origin, the imprints of several insect wings, and numerous footprints of extinct amphibians and primitive reptiles.



The positive and negative surfaces of a sandstone slab from the Coconino formation of the Grand Canyon. When the slab was split open, beautifully distinct tracks of an extinct amphibian were disclosed. As a result principally of the work of Charles W. Gilmore of the U. S. National Museum, the footprints of about thirty species of extinct amphibians and primitive reptiles have been found in Grand Canyon formations.



In caves high up on the canyon wall in the Mesa Verde region of the Southwest are the ruins of the dwellings of an ancient race. In a room of one of these buildings Dr. Merriam found that the smooth covering of mud plaster had fallen away revealing on the coating beneath innumerable prints of human fingers doubtless made by workmen centuries ago as they pressed the moist clay into the spaces between the stones of which the walls were constructed. The above specimens, photographed by Dr. Merriam, are from Antelope House, Canyon del Muerto, Arizona. They are like prints seen at Mesa Verde.



Tracks in a sandstone formation in the Jeddito Valley of New Mexico which are thought to have been made at a remote time in geological history by camel-like animals. No animals seem more foreign to North America than camels and llamas, and yet the family history was wholly North American until Pliocene time, when one branch of the family had reached Central Asia across the Bering land bridge and the other branch had reached South America. Fossil remains show that they were once widely distributed in North America.

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